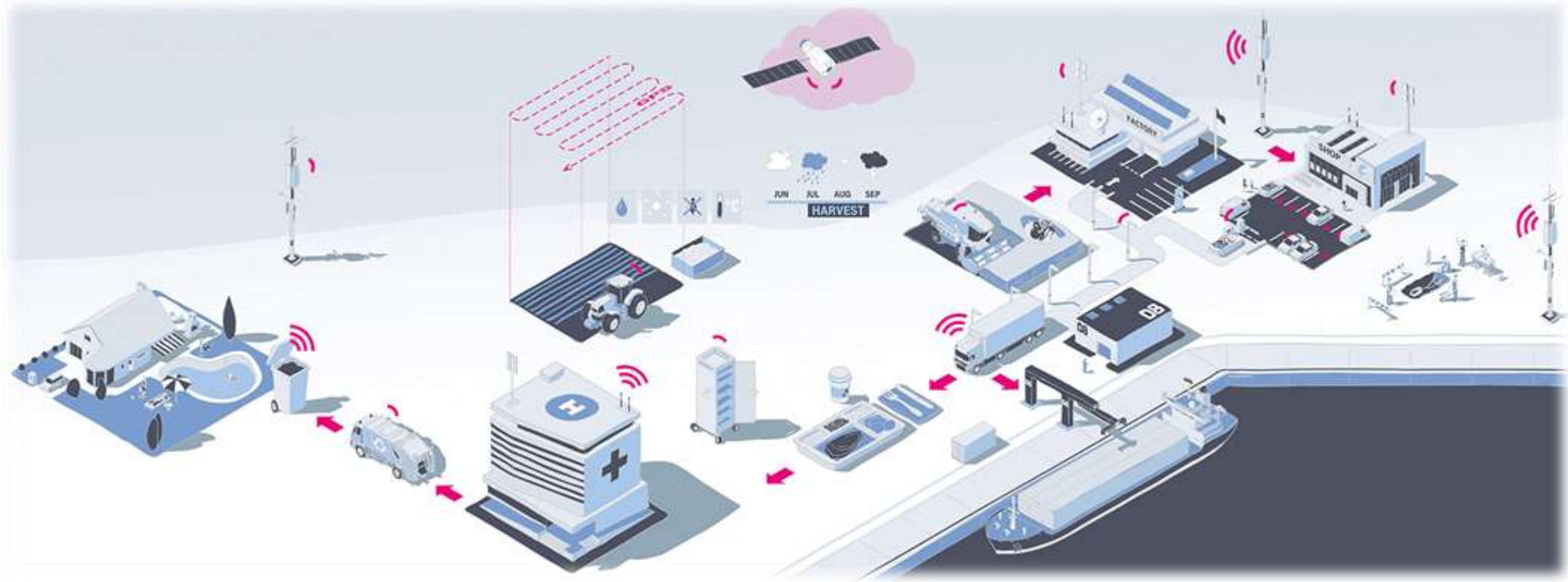# Introduction to IoT

**Prof. C.P. Gupta**
Department of Computer Sc. and Engineering,
Rajasthan Technical University, Kota

# What is IoT?

The Internet of Things (IoT) is the network of physical objects or "things" embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data.

IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration between the physical world and computer-based systems, and resulting in improved efficiency, accuracy and economic benefit.

# History of IoT

The concept of the Internet of Things first became popular in 1999, through the Auto-ID Center at MIT and related market-analysis publications. R

Radio-frequency identification (RFID) was seen as a prerequisite for the IoT at that point. If all objects and people in daily life were equipped with identifiers, computers could manage and inventory them. Besides using RFID, the tagging of things may be achieved through such technologies as near field communication, barcodes, QR codes, bluetooth, and digital watermarking.
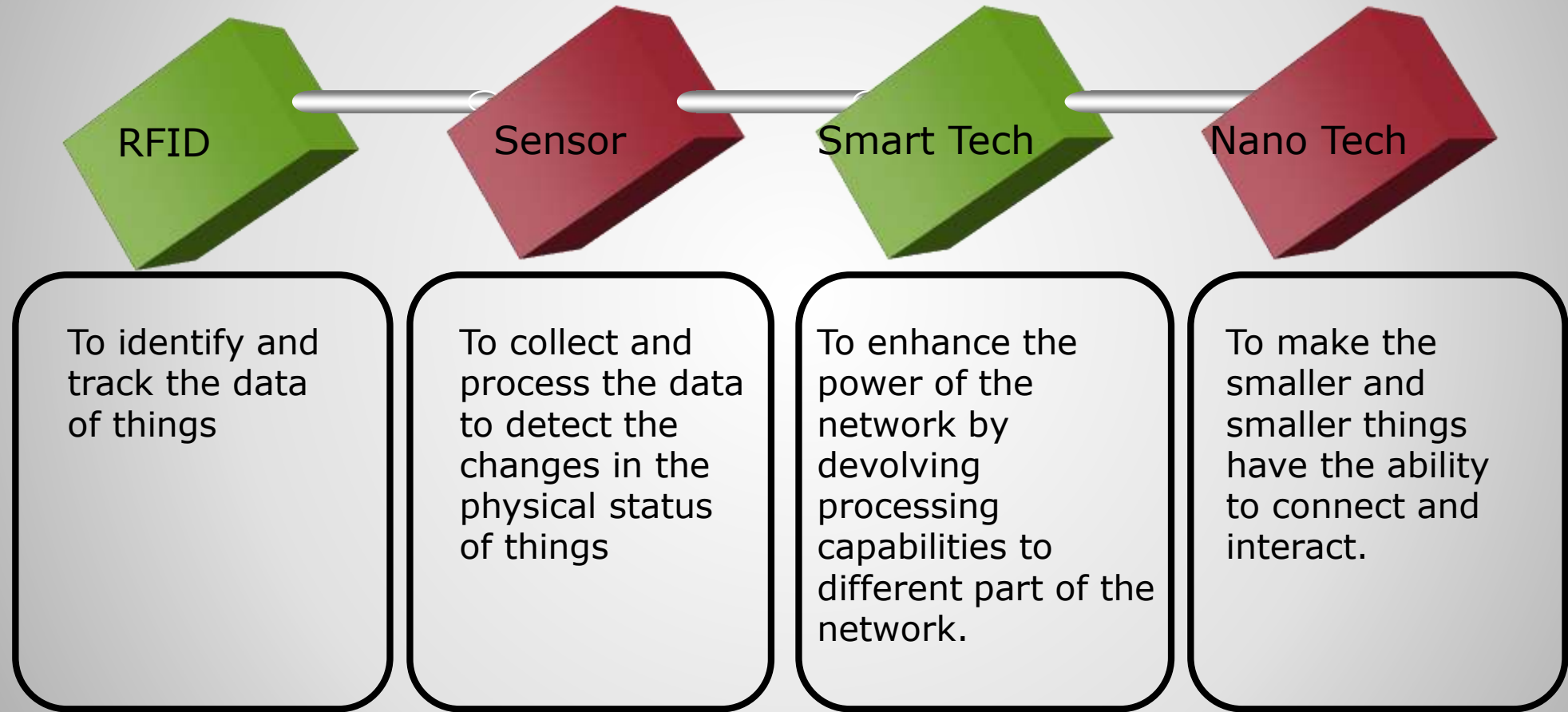
# How IoT Works?

Internet of Things is not the result of a single novel technology; instead, several complementary technical developments provide capabilities that taken together help to bridge the gap between the virtual and physical world. These capabilities include:

- *Communication and cooperation*
- *Addressability*
- *Identification*
- *Sensing*
- *Actuation*
- *Embedded information processing*
- *Localization*
- *User interfaces*

# How IoT Works?

RFID

Sensor

Smart Tech

Nano Tech

To identify and track the data of things

To collect and process the data to detect the changes in the physical status of things

To enhance the power of the network by devolving processing capabilities to different part of the network.

To make the smaller and smaller things have the ability to connect and interact.

# The Structure of IoT

The IoT can be viewed as a gigantic network consisting of networks of devices and computers connected through a series of intermediate technologies where numerous technologies like RFIDs, wireless connections may act as enablers of this connectivity.

➢ *Tagging Things* *:* Real-time item traceability and addressability by *RFID*s.

➢ *Feeling Things* *:* *Sensors* act as primary devices to collect data from the environment.

➢ *Shrinking Things* *:* Miniaturization and *Nanotechnology* has provoked the ability of smaller things to interact and connect within the "things" or "smart devices."

➢ *Thinking Things* *:* *Embedded intelligence* in devices through sensors has formed the network connection to the Internet. It can make the "things" realizing the intelligent control.
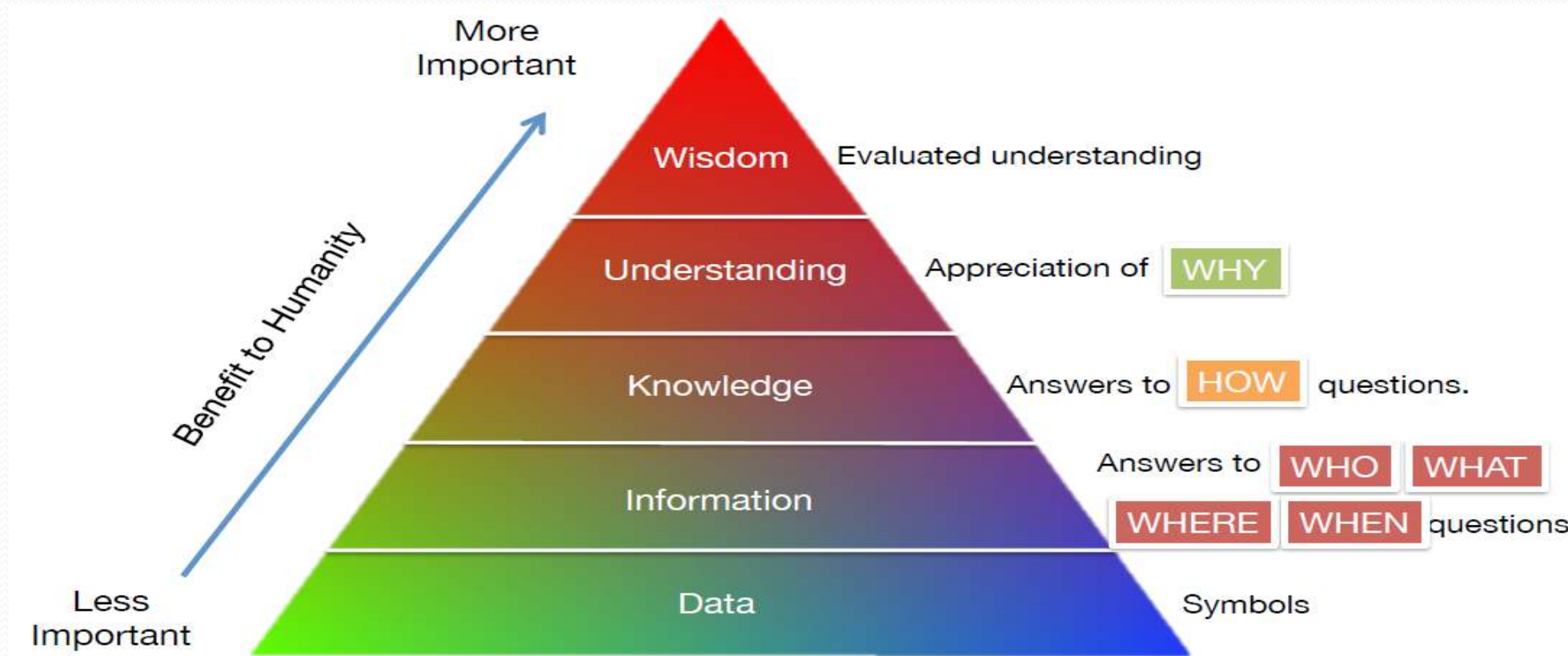
# Current Status & Future Prospect of IoT
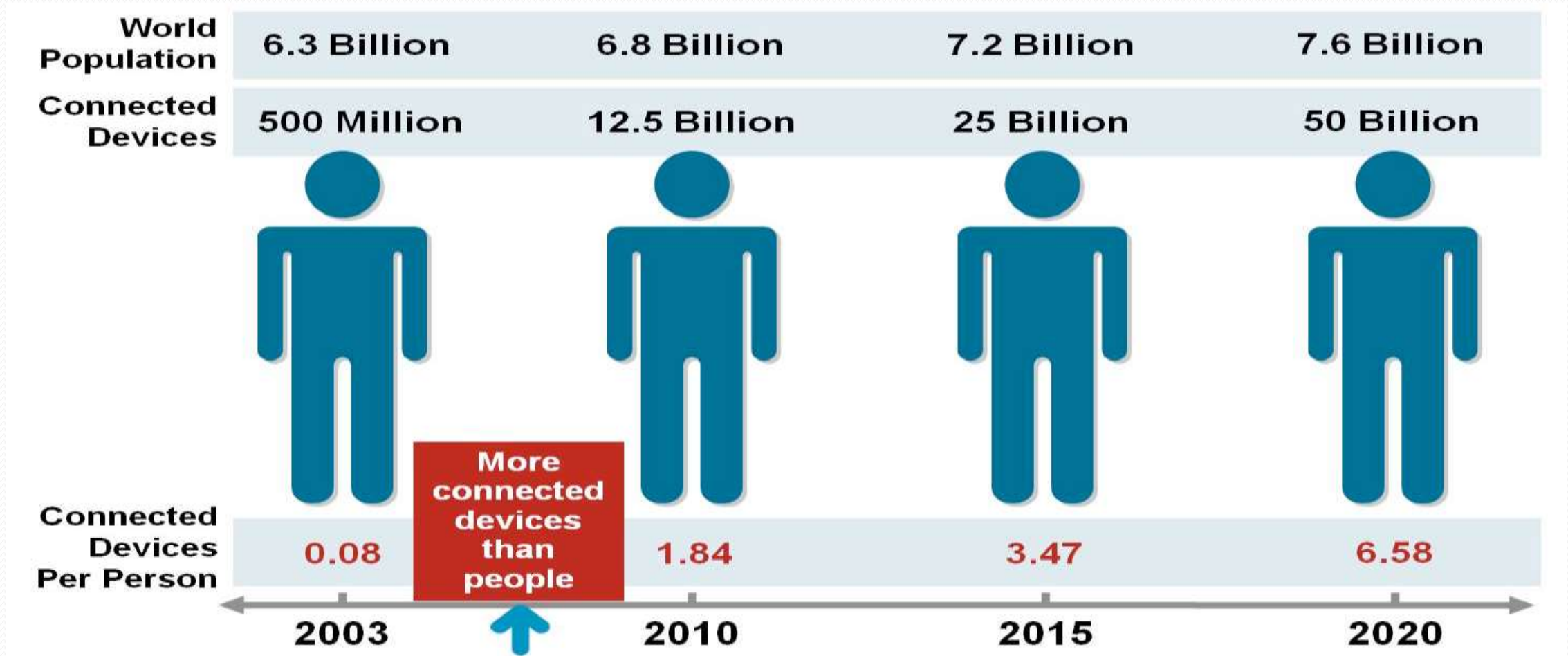


*"Change is the only thing permanent in this world"*

# **IoT as a Network of Networks:**
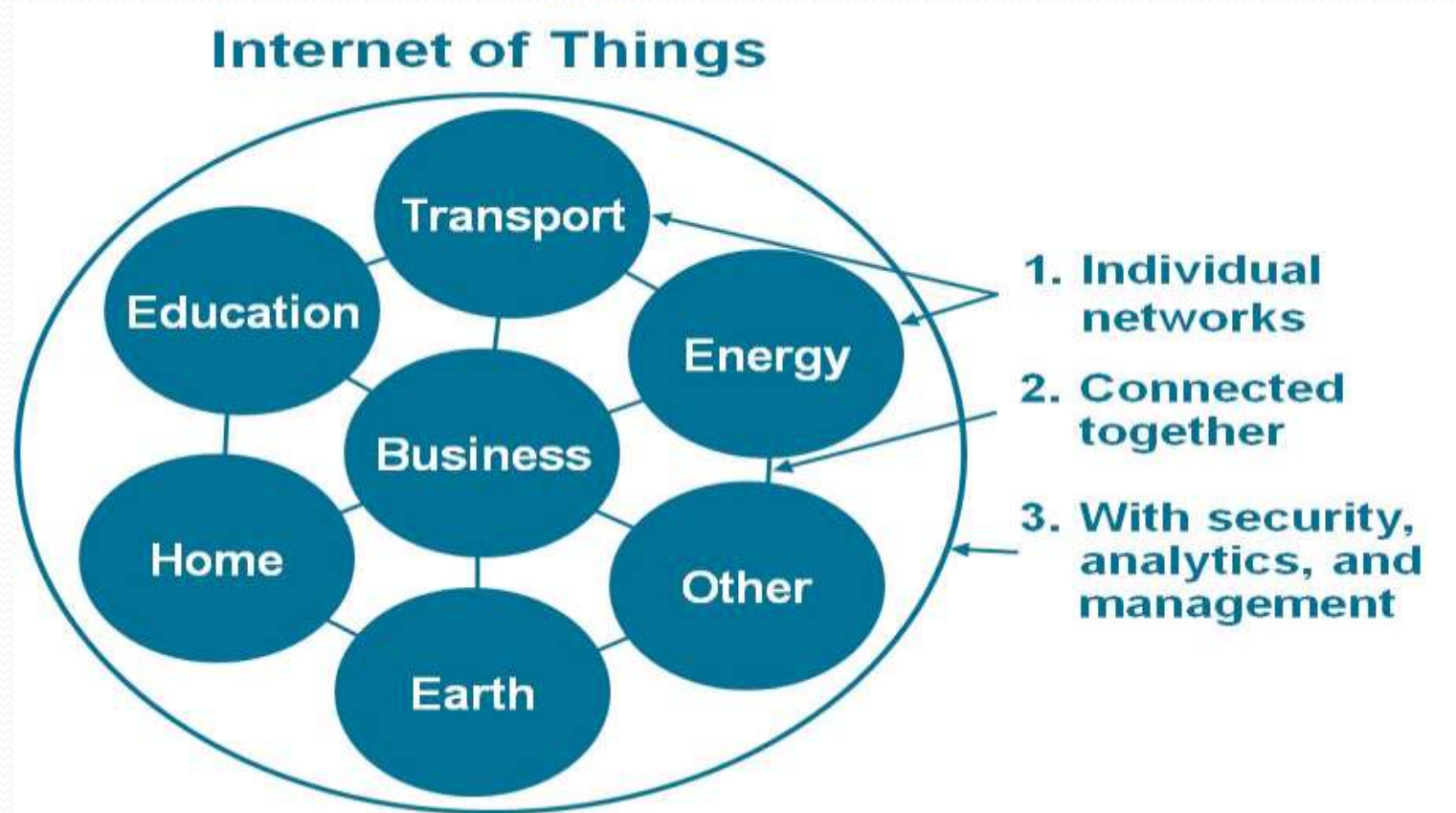


These networks connected with added security, analytics, and management capabilities. This will allow IoT to become even more powerful in what it can help people achieve.

# Knowledge Management –
# Turning Data into Wisdom



The more data that is created, the better understanding and wisdom people can obtain.

# The Future of IoT



*"The Sky's not the limit. It's only the beginning with IoT."*

# The Potential of IoT



**Value of Industrial Internet is huge**

Connected machines and data could eliminate up to $150 billion in waste across industries

| Industry | Segment | Type of savings | Estimated value over 15 years (Billion nominal US dollars) |
|---|---|---|---|
| Aviation | Commercial | 1% fuel savings | $30B |
| Power | Gas-fired generation | 1% fuel savings | $66B |
| Healthcare | System-wide | 1% reduction in system inefficiency | $63B |
| Rail | Freight | 1% reduction in system inefficiency | $27B |
| Oil and Gas | Exploration and development | 1% reduction in capital expenditures | $90B |

Note: Illustrative examples based on potential one percent savings applied across specific global industry sectors. Source: GE estimates

GE's estimates on potential of just ONE percent savings applied using IoT across global industry sectors.

# Unlock the Massive potential of IoT
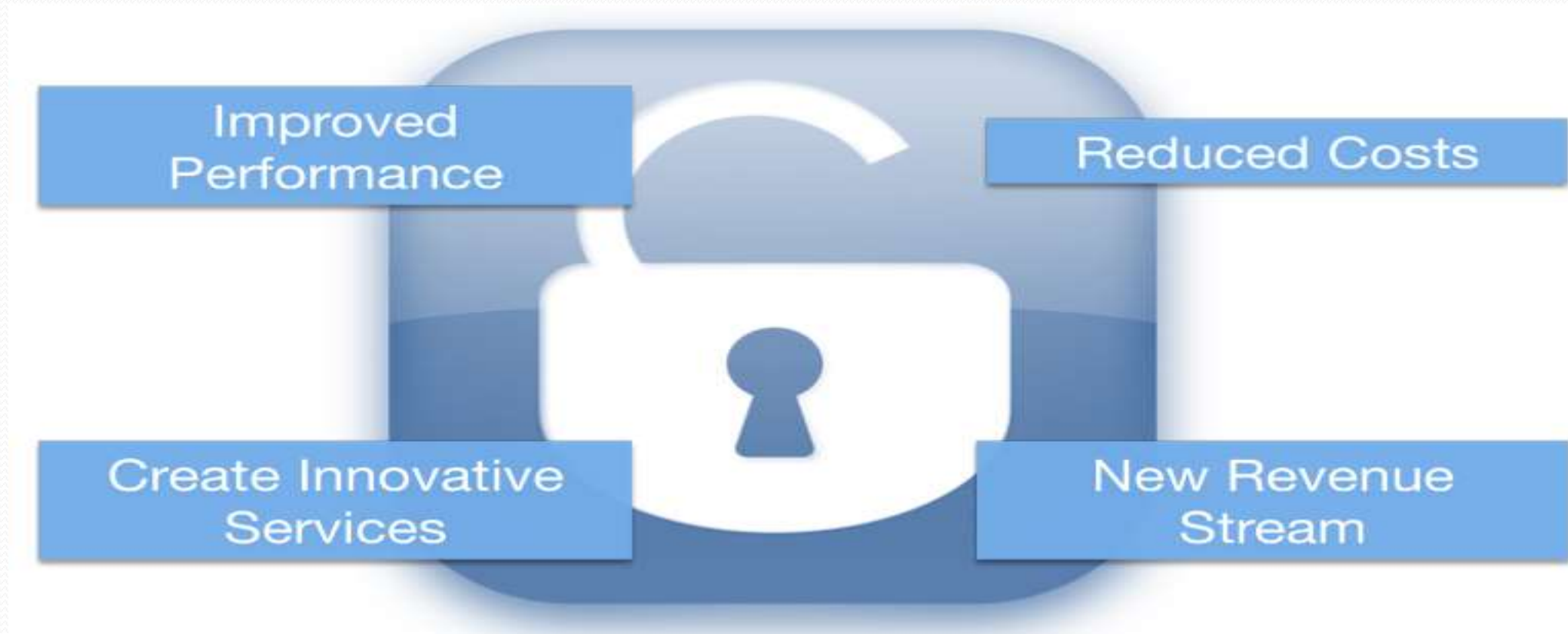
# Technology roadmap of IoT



**Technology roadmap: The Internet of Things**

Technology Reach
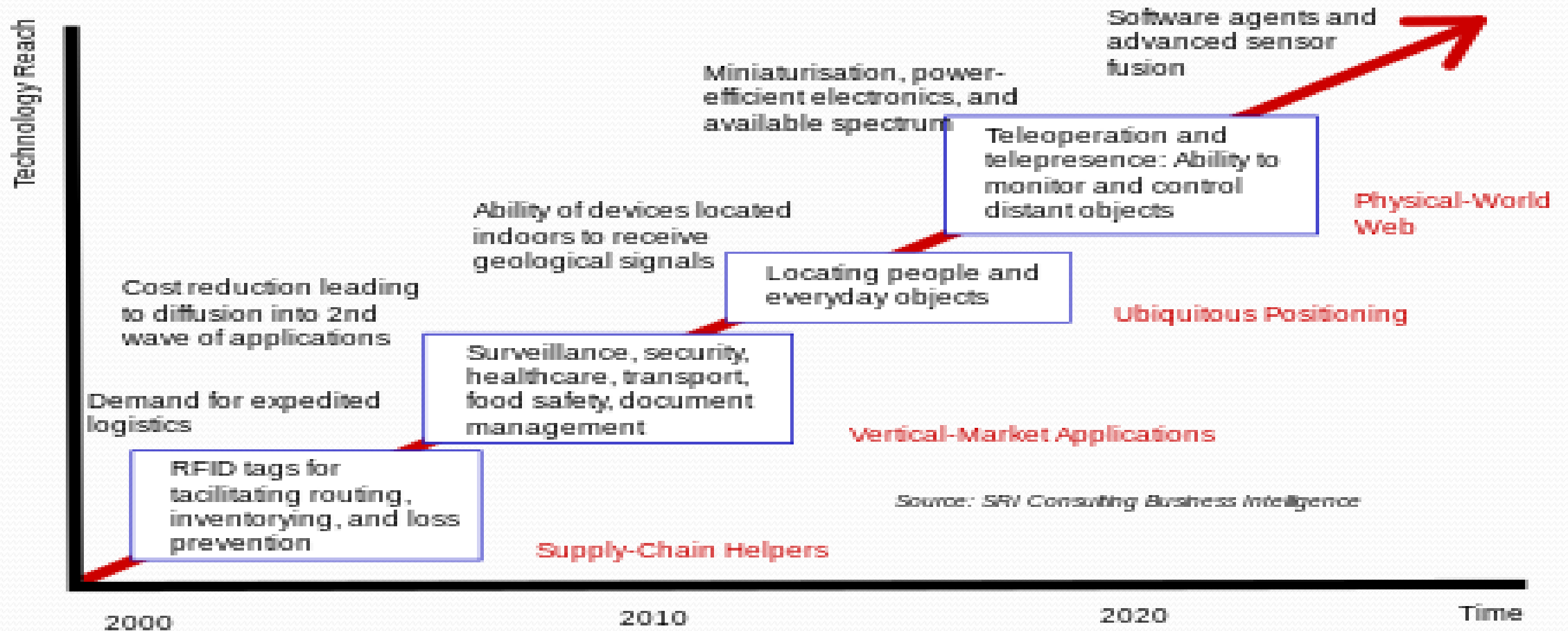
Software agents and advanced sensor fusion

Miniaturisation, power-efficient electronics, and available spectrum

Teleoperation and telepresence: Ability to monitor and control distant objects

**Physical-World Web**

Ability of devices located indoors to receive geological signals

Locating people and everyday objects

**Ubiquitous Positioning**

Cost reduction leading to diffusion into 2nd wave of applications

Surveillance, security, healthcare, transport, food safety, document management

**Vertical-Market Applications**

Demand for expedited logistics

RFID tags for facilitating routing, inventorying, and loss prevention

Source: SRI Consulting Business Intelligence

**Supply-Chain Helpers**

2000          2010          2020          Time

# What is IoT

- Internet of Things (IoT) comprises <span style="color:red">things</span> that have unique identities and are connected to the Internet

- **Network of Physical Objects**

- The focus on IoT is in the configuration, control and networking via the Internet of devices or "Things" that are traditionally not associated with the internet

  - Eg: pump, utility meter, car engine

- IoT is a new revolution in the capabilities of the <span style="color:red">endpoints that are connected to the internet</span>

# What is IoT

### Network of Physical Objects

📶 **The Scope of IoT is <span style="color:red">not limited to</span> just <span style="color:red">connecting things</span> (device, appliances, machines) to the Internet**

📶 **IoT allows these things to <span style="color:red">communicate and exchange data</span> (control& information)**

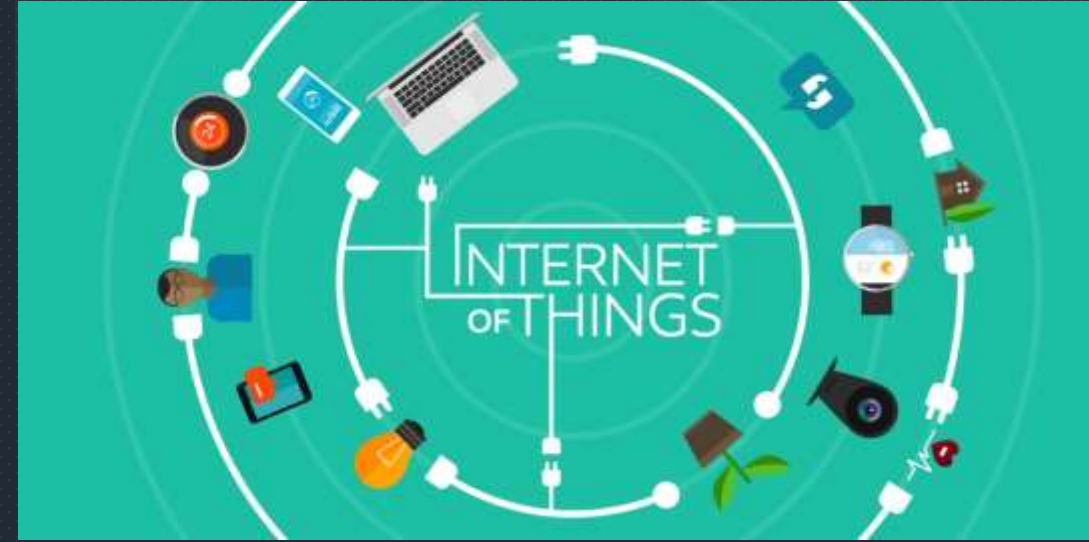📶 **Processing on these data will provide us various applications towards a common user or machine goal**

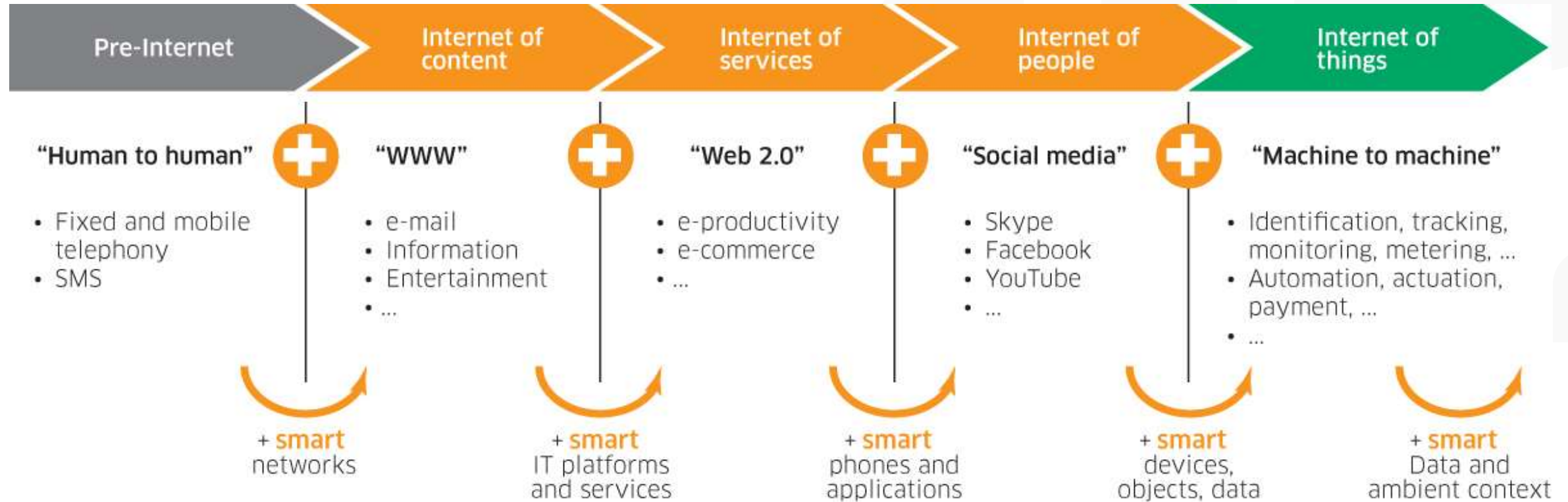# IoT

# Idea: Move from Internet of People → Internet of Things

Internet appears everywhere in the world

❖ It is primarily connection between people

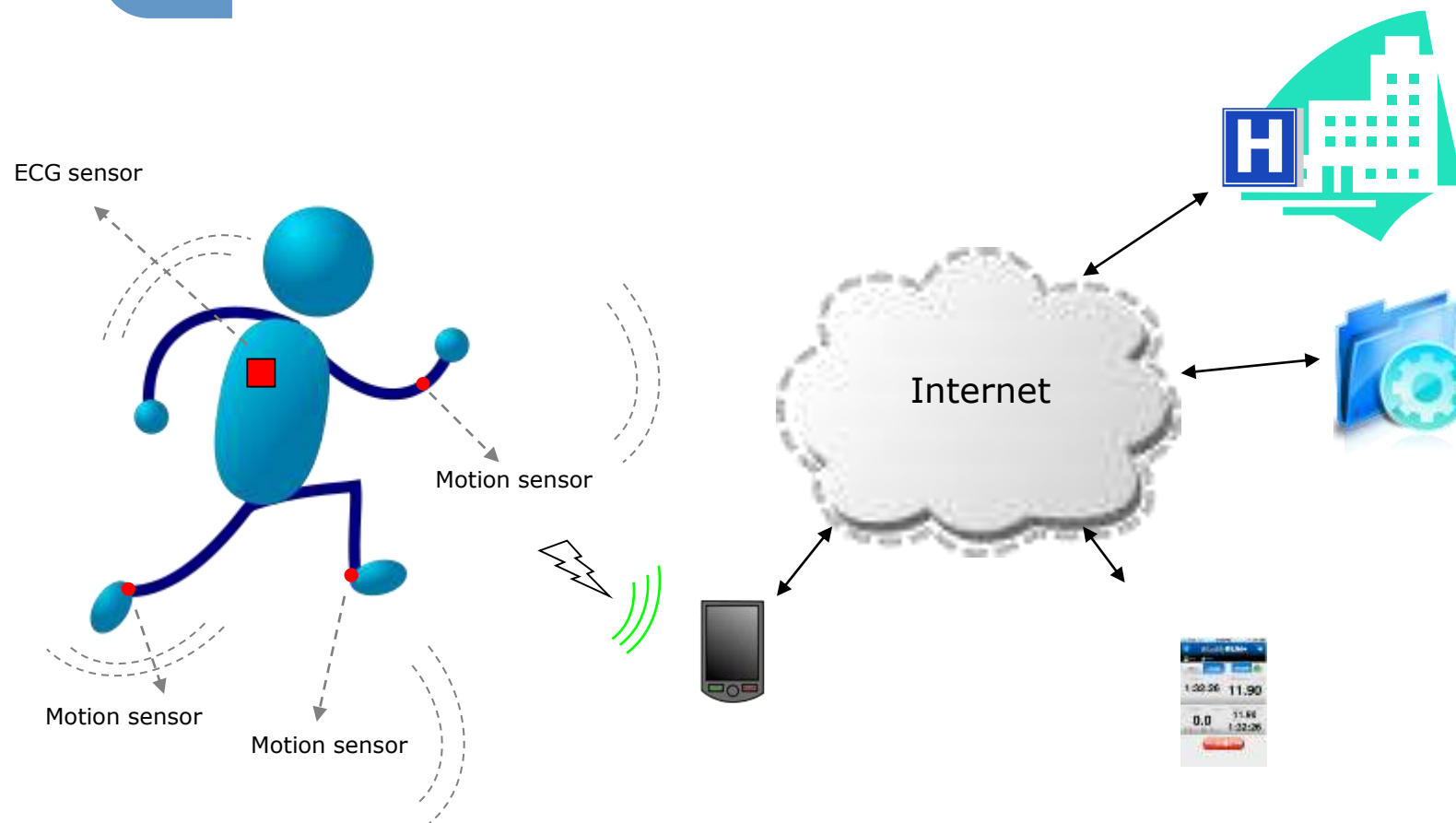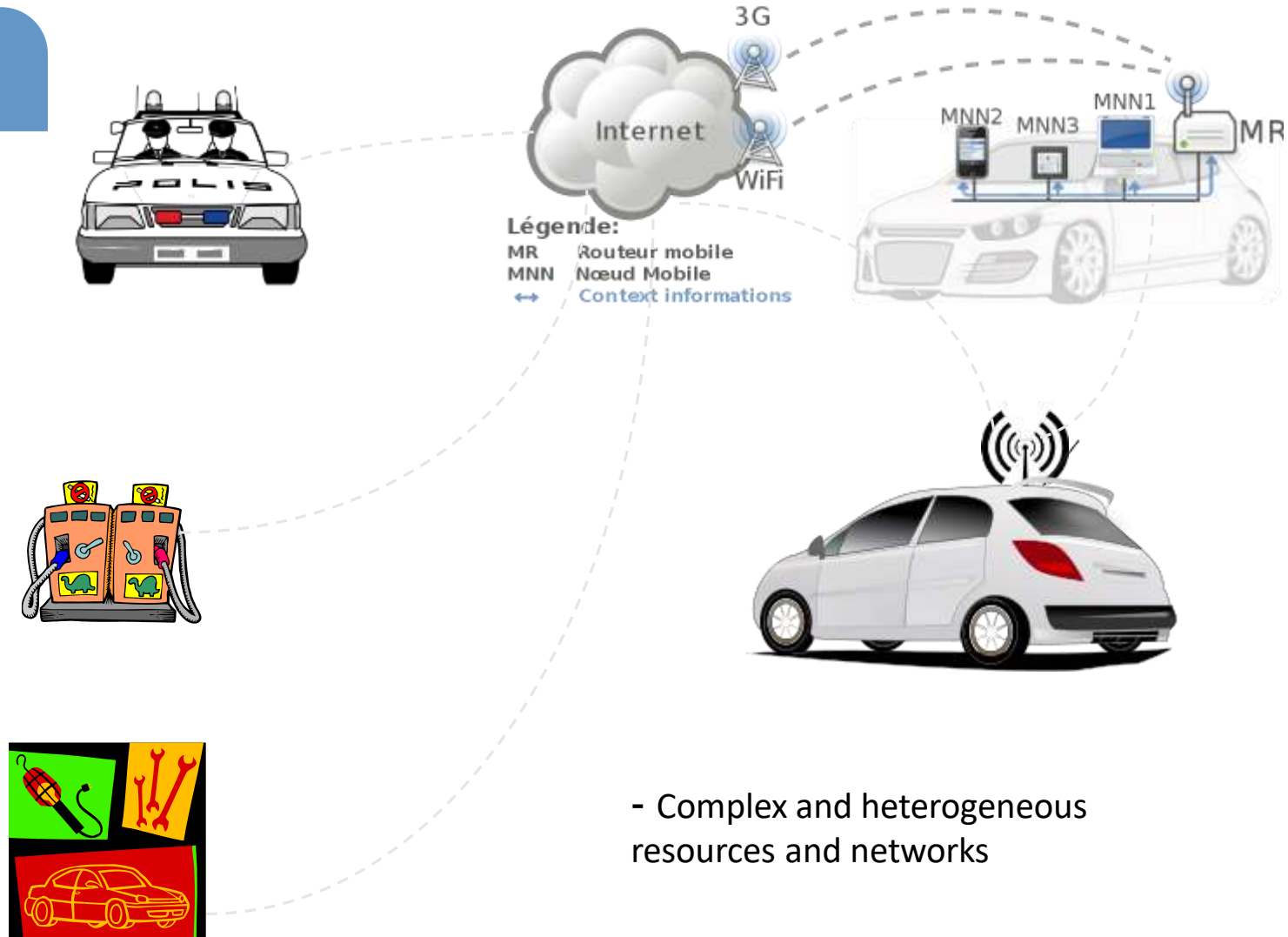❖ Internet of Things is a plan to connect things also using the same medium

# Internet of Things - Evolution

# IOT: People connecting with Things



ECG sensor

Motion sensor

Motion sensor

Motion sensor

Internet

# IoT: Things connecting with Things

3G

Internet

WiFi

MNN2 MNN3 MNN1 MR

Légende:
MR      Routeur mobile
MNN    Nœud Mobile
↔       Context informations

**-** Complex and heterogeneous resources and networks

# Looming Opportunity

**Consumer**
- Smart home control (lighting, security, comfort)
- Optimized energy use
- Maintenance

**Retail**
- Product tracking
- Inventory control
- Focused marketing

**Medical**
- Wearable devices
- Implanted devices
- Telehealth services

**Military**
- Resource allocation
- Threat analysis
- Troop monitoring

**Industrial**
- SmartMeters
- Wear-out sensing
- Manufacturing control
- Climate control

**Automotive**
- Parking
- Traffic flow
- Anti-theft location

**Environmental**
- Species tracking
- Weather prediction
- Resource management

**Agriculture**
- Crop management
- Soil analysis

# APPLICATIONS OF IOT

# IoT Applications : Intelligent Home



Source: Raymond James research.

# Smart Egg Tray

Egg Minder syncs with your smartphone to tell you how many eggs you've got at home (up to 14 eggs) and when they're going bad.

http://www.quirky.com/shop/619

# Smart Washing Machine

Smart Aqualtis is the first Indesit Company washing machine designed to be integrated in 'Smart' ecosystems, covering a wide range of use cases.

http://zigbee.org/Products/ByStandard/AllStandards.aspx

# Smart Lighting

Control your bulbs one at a time or altogether. Find just the right shade of white. Pick that perfect tone to match the moment. Or recreate any color from a photo.

http://meethue.com/

# Smart A/C

Aros learns from your budget, location, schedule, and usage to automatically maintain the perfect temperature and maximize savings for your home.

https://www.quirky.com/shop/752-aros-smart-window-air-conditioner

# Smart Sleep System

Visualize your sleep cycles, understand what wakes you up, and compare nights. From the palm of your hand you can control your personalized wake-up, and fall-asleep programs.

http://www.withings.com/us/withings-aura.html

# Smart Weather Station

The Netatmo Weather Station allows you to use indoor temperature, relative humidity and $CO_2$ readings to live in a healthier home.

http://www.netatmo.com/en-US/product/weather-station/

# Smart Slow Cooker

Enjoy remote access to all your slow cooker's functions, no matter where you are.

http://www.belkin.com/us/Products/home-automation/c/wemo-home-automation/

# Smart Garbage Cans

BigBelly alerts when it needs to be emptied so smarter collection decisions can be made.

http://www.bigbelly.com/solutions/stations/smartbelly/

# Smart Gardening

Bitponics gives data on plants and conditions surrounding them for better gardening.

http://www.bitponics.com/

# IoT

- Internet Of Things is Fully Networked and Connected Devices sending analytics data back to cloud or data center.

- The definition of Internet of things is that it is the network in which every object or **thing is provided unique identifier** and data is transferred through a network without any verbal communication.

- **Scope of IoT is not just limited to just connecting things to the internet, but it allows these things to communicate and exchange data, process them as well as control them while executing applications.**

# Formal Definition of IoT

- A **dynamic global network** infrastructure with **self- configuring capabilities** based on standard and **interoperable communication protocols,** where physical and virtual "things" have **identities,** physical attributes, and use intelligent interfaces, and are seamlessly **integrated into information network** that communicate data with users and environments.

# Characteristics of IoT

- **Dynamic Global network & Self-Adapting** : Adapt the changes w.r.t changing contexts

- **Self Configuring** : Eg. Fetching latest s/w updates without manual intervention.

- **Interoperable Communication Protocols** : Communicate through various protocols

- **Unique Identity** : Such as Unique IP Address or a URI

- **Integrated into Information Network** : This allows to communicate and exchange data with other devices to perform certain analysis.

# Physical Design of IoT

- Things in IoT
- IoT Protocols

# Things in IoT

- Refers to IoT devices which have unique identities that can perform sensing, actuating and monitoring capabilities.

- IoT devices can exchange data with other connected devices or collect data from other devices and process the data either locally or send the data to centralized servers or cloud – based application back-ends for processing the data.

# IoT Architecture



**Integrated Application**

Smart Grid    Green Building    Smart Transport    Env. Monitor

**Information Processing**
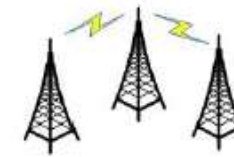
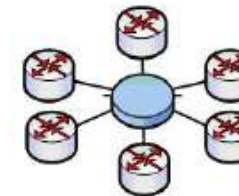Data Center    Search Engine    Smart Decision    Info. Security    Data Mining

**Network Construction**

WWAN    WMAN    WPAN    Internet    WLAN

**Sensing & Identification**

GPS    Smart Device    RFID    Sensor    Sensor

# TECHNOLOGICAL CHALLENGES OF IoT

At present IoT is faced with many challenges, such as:

- Scalability
- Technological Standardization
- Inter operability
- Discovery
- Software complexity
- Data volumes and interpretation
- Power Supply
- Interaction and short range communication
- Wireless communication
- Fault tolerance

# Criticisms and Controversies of IoT

Scholars and social observers and pessimists have doubts about the promises of the ubiquitous computing revolution, in the areas as:

- Privacy
- Security
- Autonomy and Control
- Social control
- Political manipulation
- Design
- Environmental impact
- Influences human moral decision making

# IoT Technologies

# IoT Technologies

- Hardware (Device)

- Communication Technology
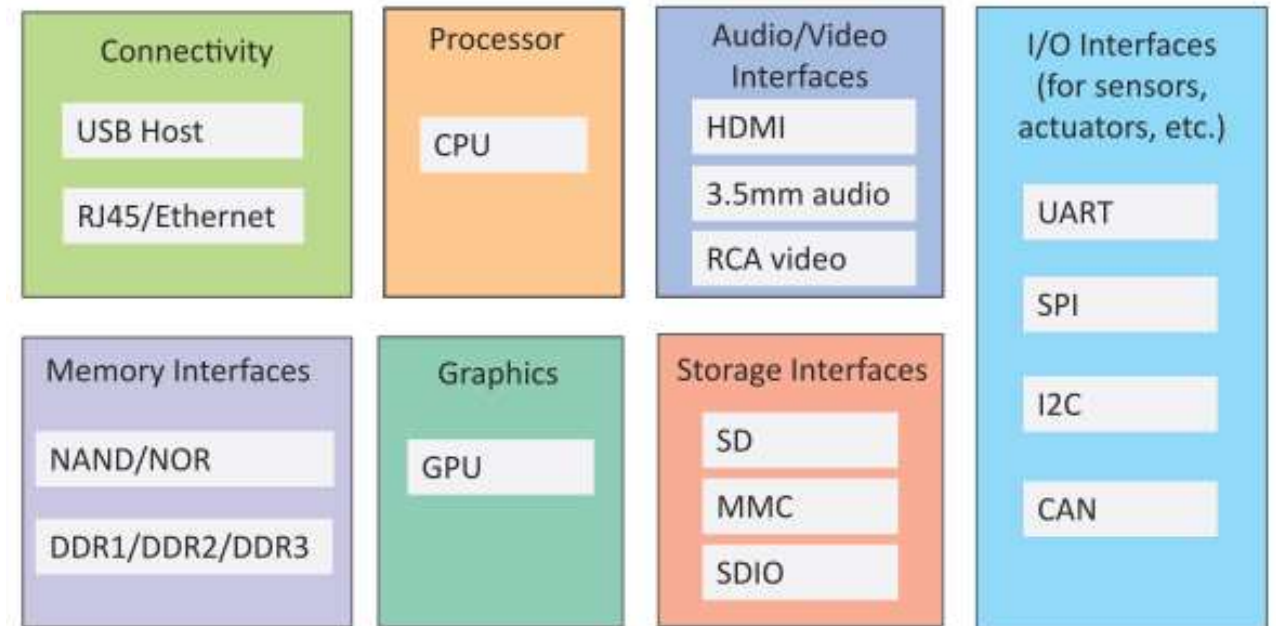
- Protocols for IoT

- Software (IDE)

- Cloud Platforms

# Generic Block Diagram of an IoT Device

- An IoT device may consist of several interfaces for connections to other devices, both wired and wireless.
  - I/O interfaces for sensors
  - Interfaces for internet connectivity
  - Memory and storage interfaces
  - Audio/video interfaces

**Connectivity**
- USB Host
- RJ45/Ethernet

**Processor**
- CPU

**Audio/Video Interfaces**
- HDMI
- 3.5mm audio
- RCA video

**I/O Interfaces (for sensors, actuators, etc.)**
- UART
- SPI
- I2C
- CAN

**Memory Interfaces**
- NAND/NOR
- DDR1/DDR2/DDR3

**Graphics**
- GPU

**Storage Interfaces**
- SD
- MMC
- SDIO

# Implementing Smart Objects



Beaglebone black



Intel Galileo



Raspberry Pi



Arduino Uno

# Board Connection

# Sensors and Actuators



Machine Vision / Optical Ambient Light

Position / Presence / Proximity

Acceleration / Tilt

Motion / Velocity / Displacement

Electric / Magnetic

Temperature

Leaks / Levels

Humidity / Moisture

Force / Load / Torque Strain / Pressure

Acoustic / Sound / Vibration

Flow

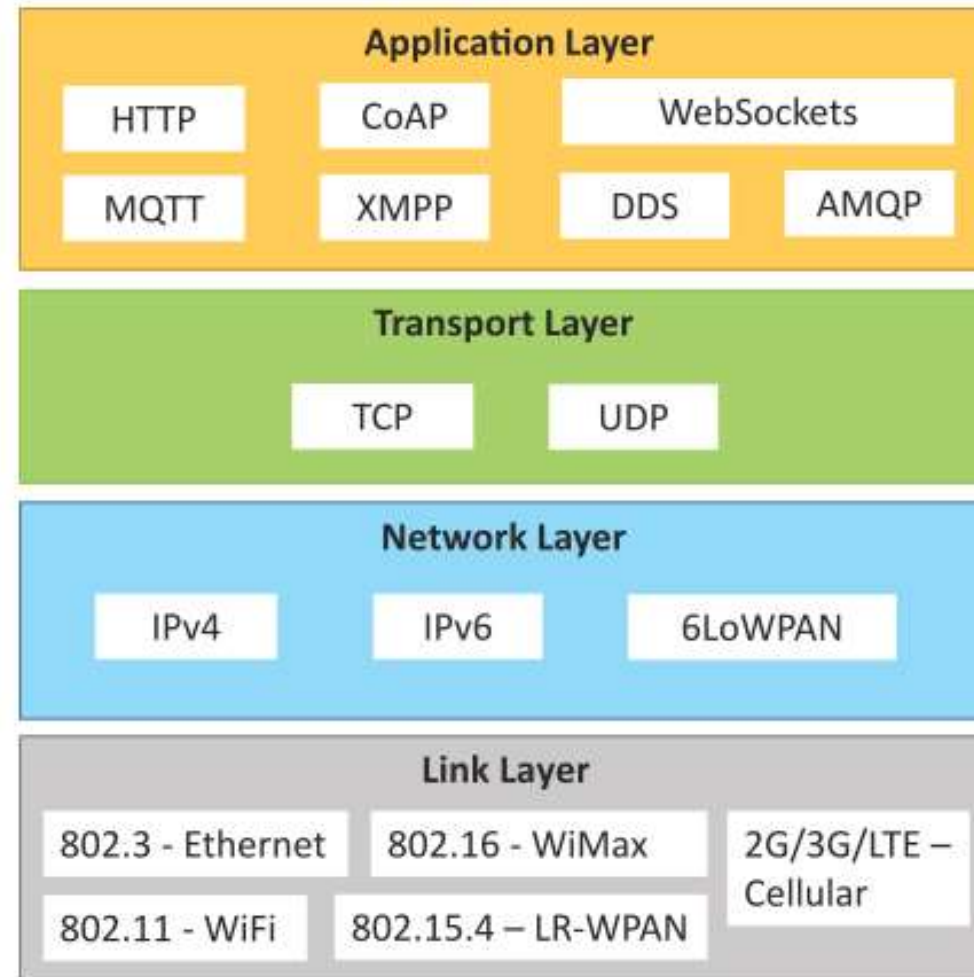Chemical / Gas
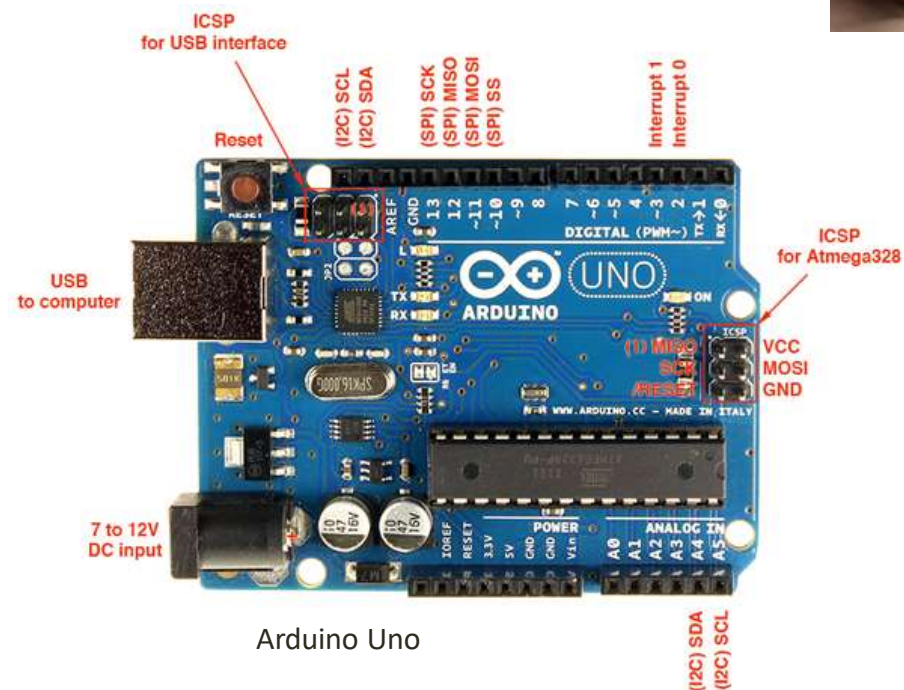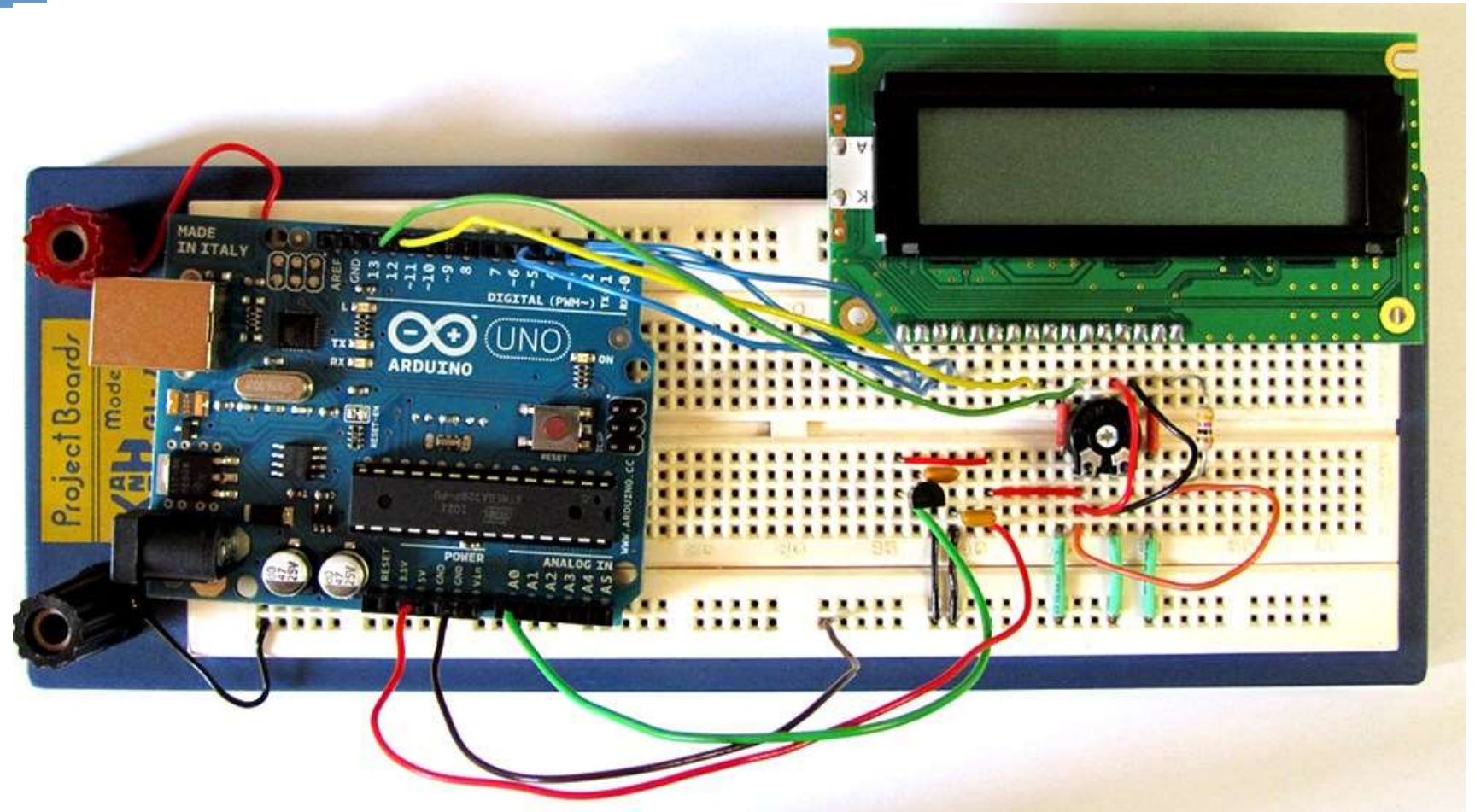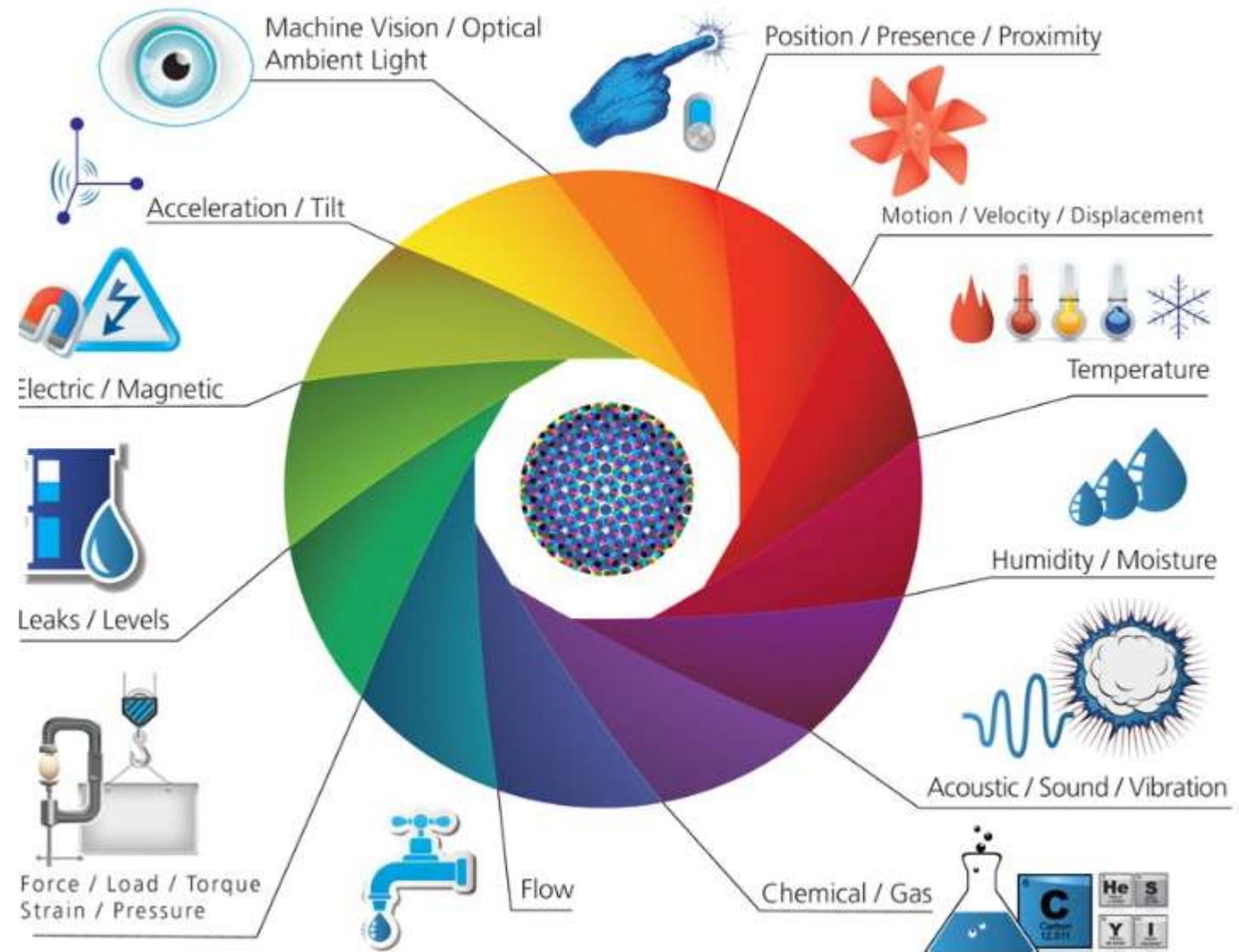
# IoT Protocols

- Link Layer
  - 802.3 – Ethernet
  - 802.11 – WiFi
  - 802.16 – WiMax
  - 802.15.4 – LR-WPAN
  - 2G/3G/4G
- Network/Internet Layer
  - IPv4
  - IPv6
  - 6LoWPAN
- Transport Layer
  - TCP
  - UDP
- Application Layer
  - HTTP
  - CoAP
  - WebSocket
  - MQTT
  - XMPP
  - DDS
  - AMQP

# IoT Protocols…Link Layer…WiFi

- Collection of Wireless LAN
- Data Rates from 1Mb/s to 6.75 Gb/s

| Sr.No | Standard | Operates in |
|-------|----------|-------------|
| 1 | 802.11a | 5 GHz band |
| 2 | 802.11b and 802.11g | 2.4GHz band |
| 3 | 802.11.n | 2.4/5 GHz bands |
| 4 | 802.11.ac | 5GHz band |
| 5 | 802.11.ad | 60Hz band |

# IoT Protocols…Link Layer…WiMax

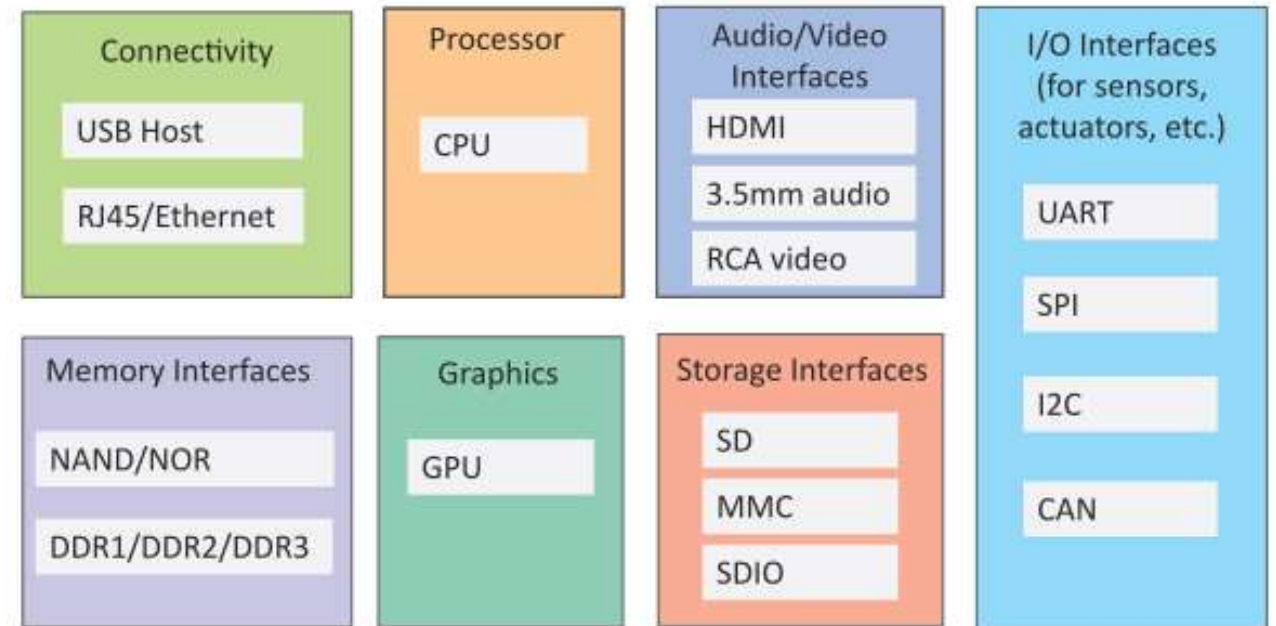| Sr.No | Standard | Data Rate |
|-------|----------|-----------|
| 1 | 802.16m | 100Mb/s for mobile stations<br>1Gb/s for fixed stations |

- Collection of Wireless Broadband standards
- Data Rates from 1.5Mb/s to 1 Gb/s
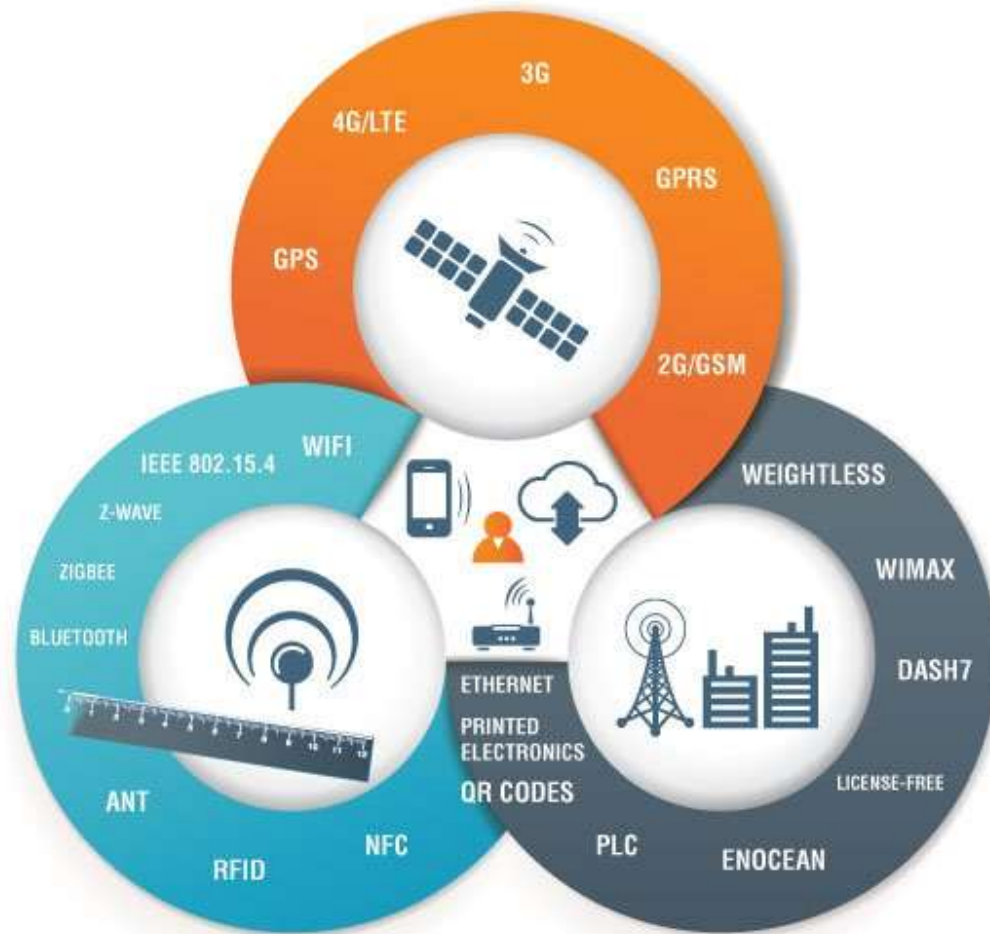
# IoT Protocols…Link Layer…LR-WPAN

- Collection of standards for low-rate wireless personal area networks

- Basis for high level communication protocols such as Zigbee

- Data Rates from 40Kb/s to 250Kb/s

- Provide low-cost and low-speed communication for power constrained devices

# Generic Block Diagram of an IoT Device

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- CAN

**Memory Interfaces**
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- DDR1/DDR2/DDR3

**Graphics**
- GPU

**Storage Interfaces**
- SD
- MMC
- SDIO

# IoT Technologies : Communication Technology

# IoT Technologies : Protocols

📡  CoAP ( Constrained Application Protocol)

📡  MQTT (Message Queue Telemetry Transport)

📡  XMPP (Extensible Messaging and Presence Protocol)

📡  6LoWPAN (Low power Wireless Personal Area Networks)

# IoT Protocols...Link Layer...LR-WPAN

- Collection of standards for low-rate wireless personal area networks

- Basis for high level communication protocols such as Zigbee

- Data Rates from 40Kb/s to 250Kb/s

- Provide low-cost and low-speed communication for power constrained devices

# IoT Protocols…Link Layer…2G/3G/4G –Mobile Communication

| Sr.No | Standard | Operates in |
|-------|----------|-------------|
| 1 | 2G | GSM-CDMA |
| 2 | 3G | UMTS and CDMA 2000 |
| 3 | 4G | LTE |

- Data Rates from 9.6Kb/s (for 2G) to up to 100Mb/s (for 4G)

# IoT Protocols…Network/Internet Layer

- Responsible for sending of IP datagrams from source to destination network

- Performs the host addressing and packet routing

- Host identification is done using hierarchical IP addressing schemes such as IPV4 or IPV6

# IoT Protocols…Network Layer

- IPV4

- IPV6

- 6LoWPAN (IPV6 over Low power Wireless Personal Area Network)

  - Used for devices with limited processing capacity

  - Operates in 2.4 GHz

  - Data Rates of 250Kb/s

# IoT Protocols…Transport Layer

- Provides end-to-end message transfer capability independent of the underlying network

- It provides functions such as error control, segmentation, flow-control and congestion control

# IoT Protocols…TCP

- Transmission Control Protocol
- Connection Oriented
- Ensures Reliable transmission
- Provides Error Detection Capability to ensure no duplicity of packets and retransmit lost packets
- Flow Control capability to ensure the sending data rate is not too high for the receiver process
- Congestion control capability helps in avoiding congestion which leads to degradation of n/w performance

# IoT Protocols...UDP

- User Datagram Protocol
- Connectionless
- Does not ensures Reliable transmission
- Does not do connection before transmitting
- Does not provide proper ordering of messages
- Transaction oriented and stateless

# IoT Protocols…Application Layer…Hyper Transfer Protocol

- Forms foundation of World Wide Web(WWW)

- Includes commands such as GET,PUT, POST, HEAD, OPTIONS, TRACE..etc

- Follows a request-response model

- Uses Universal Resource Identifiers(URIs) to identify HTTP resources

# IoT Protocols…Application Layer…CoAP

- Constrained Application Protocol
- Used for Machine to machine (M2M) applications meant for constrained devices and n/w's
- Web transfer protocol for IoT and uses request-response model
- Uses client –server architecture
- Supports methods such as GET,POST, PUT and DELETE



CoAP

Constrained Application Protocol
(Web Protocol for IoT)
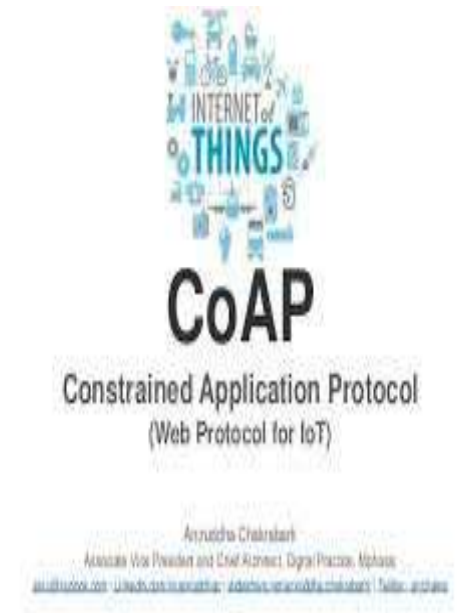
# IoT Protocols…Application Layer…WebSocket

- Allows full-duplex communication over single socket
- Based on TCP
- Client can be a browser, IoT device or mobile application

# IoT Protocols…Application Layer…MQTT

- Message Queue Telemetry Transport , light-weight messaging protocol
- Based on publish-subscribe model
- Well suited for constrained environments where devices have limited processing, low memory and n/w bandwith requirement

# IoT Protocols…Application Layer…XMPP

- eXtensible Messaging and Presence Protocol
- For Real time communication and streaming XML data between n/w entities
- Used for Applications such as Multi-party chat and voice/video calls.
- Decentralized protocol and uses client server architecture.

# IoT Protocols…Application Layer…DDS

- Data Distribution Service is a data-centric middleware standard for device-to-device or machine-to-machine communication.
- Publish subscribe model where publishers create topics to which subscribers can use.
- Provides Quality-of-service control and configurable reliability.

# IoT Protocols…Application Layer…AMQP

- Advanced Messaging Queuing Protocol used for business messaging.
- Supports both point-to-point and publisher/subscriber models, routing and queuing
- Broker here receives messages from publishers and route them over connections to consumers through messaging queues.

# Logical Design of IoT

- Logical design of an IoT system refers to an abstract representation of the entities and processes without going into the low-level specifics of the implementation.

- An IoT system comprises a number of functional blocks that provide the system the capabilities for identification, sensing, actuation, communication and management.
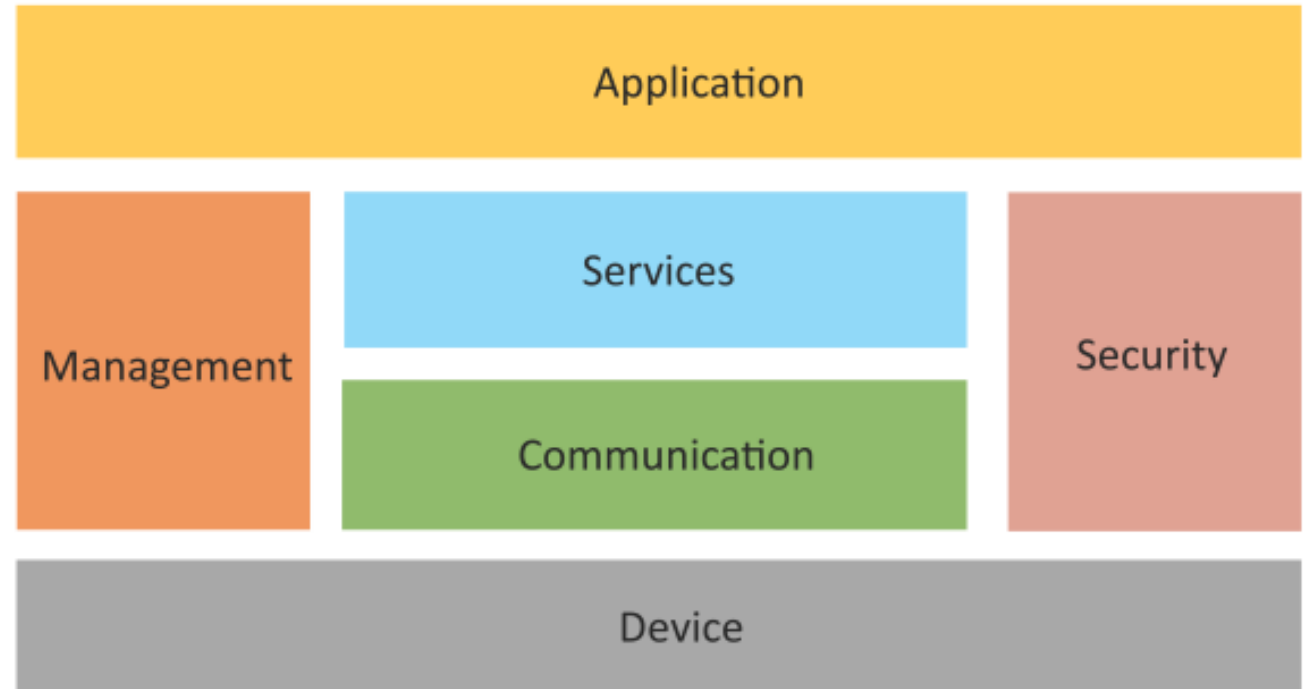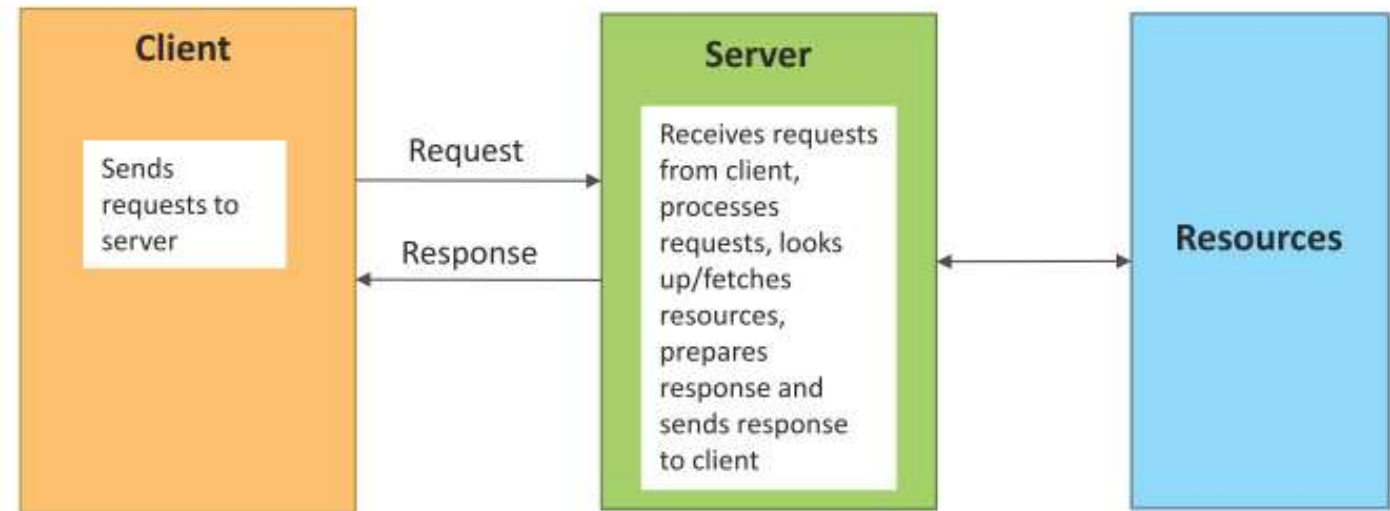
# Logical Design of IoT

- Device: Devices such as sensing, actuation, monitoring and control functions.

- Communication: IoT Protocols

- Services like device monitoring, device control services, data publishing services and device discovery

- Management: Functions to govern the system

- Security: Functions as authentication, authorization, message and content integrity, and data security

- Applications

# Request–Response Communication Model

- Request–Response is a communication model in which the client sends requests to the server and the server responds to the requests.

- When the server receives a request, it decides how to respond, fetches the data, retrieves resource representations, prepares the response and then sends the response to the client.

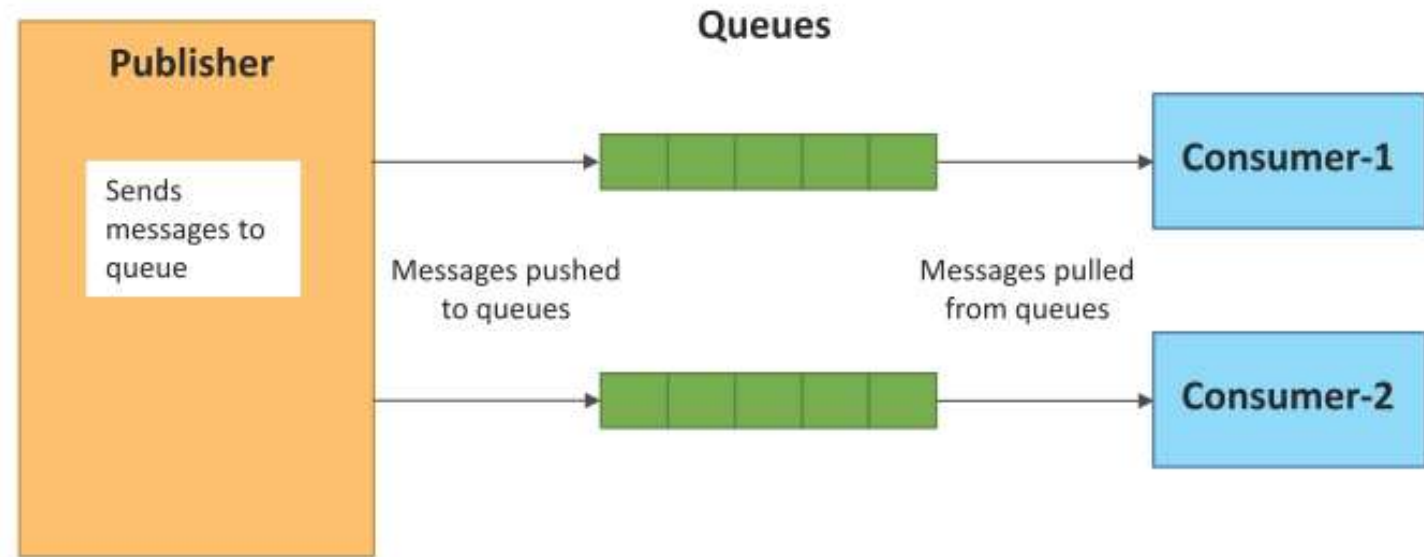- Stateless communication model

**Client**

Sends requests to server

Request →

← Response

**Server**

Receives requests from client, processes requests, looks up/fetches resources, prepares response and sends response to client

**Resources**

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# Publish–Subscribe Communication Model

- Publish–Subscribe is a communication model that involves publishers, brokers and consumers.

- Publishers are the source of data. Publishers send the data to the topics which are managed by the broker. Publishers are not aware of the consumers.

- Consumers subscribe to the topics which are managed by the broker.

- When the broker receives data for a topic from the publisher, it sends the data to all the subscribed consumers.



73
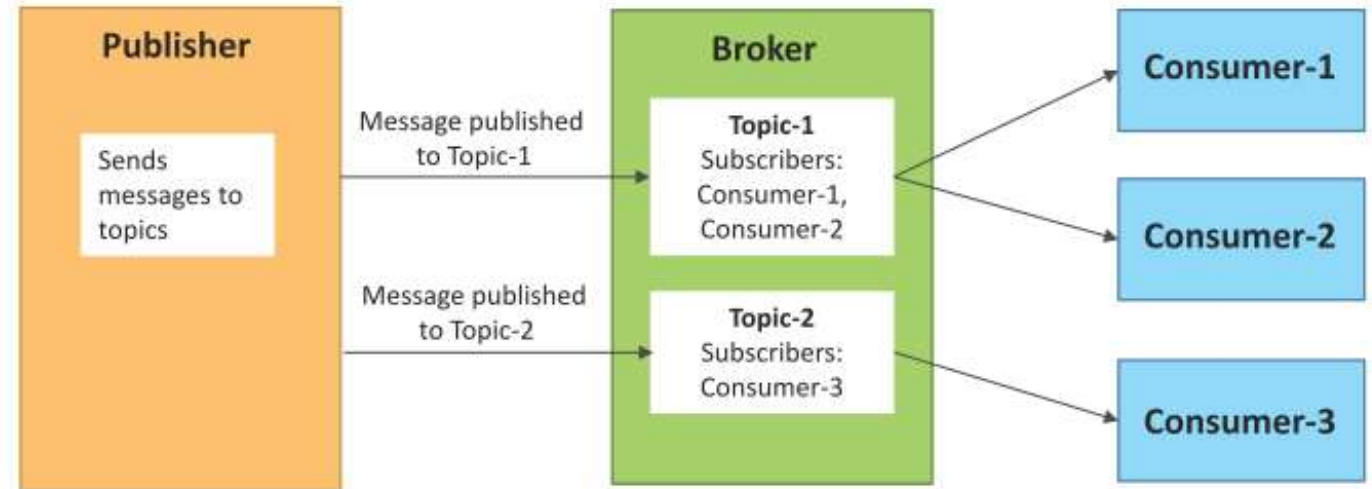
# Push–Pull Communication Model

- Push–Pull is a communication model in which the data producers push the data to queues and the consumers pull the data from the queues. Producers do not need to be aware of the consumers.

- Queues help in decoupling the messaging between the producers and consumers.

- Queues also act as a buffer which helps in situations when there is a mismatch between the rate at which the producers push data and the rate at which the consumers pull data.



Publisher

Sends messages to queue

Queues

Messages pushed to queues

Messages pulled from queues

Consumer-1

Consumer-2

# Exclusive Pair Communication Model

- Exclusive Pair is a bidirectional, fully duplex communication model that uses a persistent connection between the client and the server.

- Once the connection is set up it, remains open until the client sends a request to close the connection.

- Client and server can send messages to each other after connection setup.
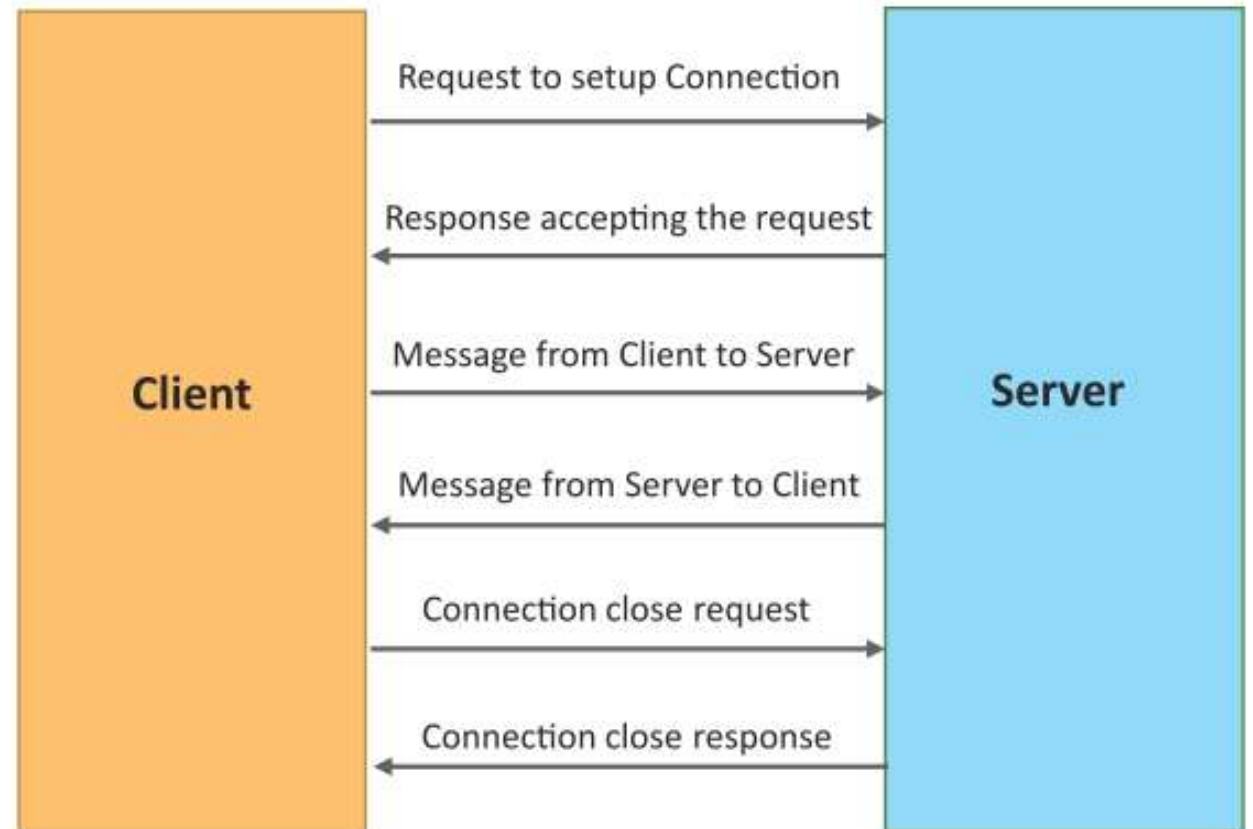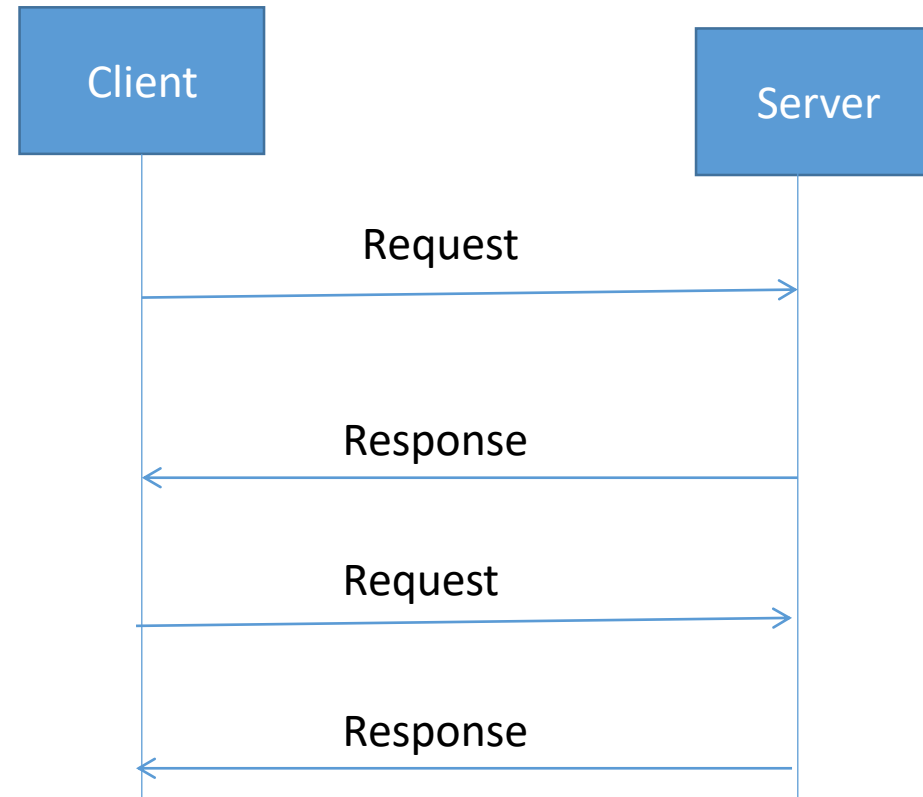
# REST-based Communication APIs

- Representational State Transfer (REST) is a set of architectural principles by which you can **design web services and web APIs** that focus on a system's resources and how resource states are addressed and transferred.

- REST APIs **follow the request–response communication model.**

- REST architectural constraints apply to the components, connectors and data elements within a distributed hypermedia system.
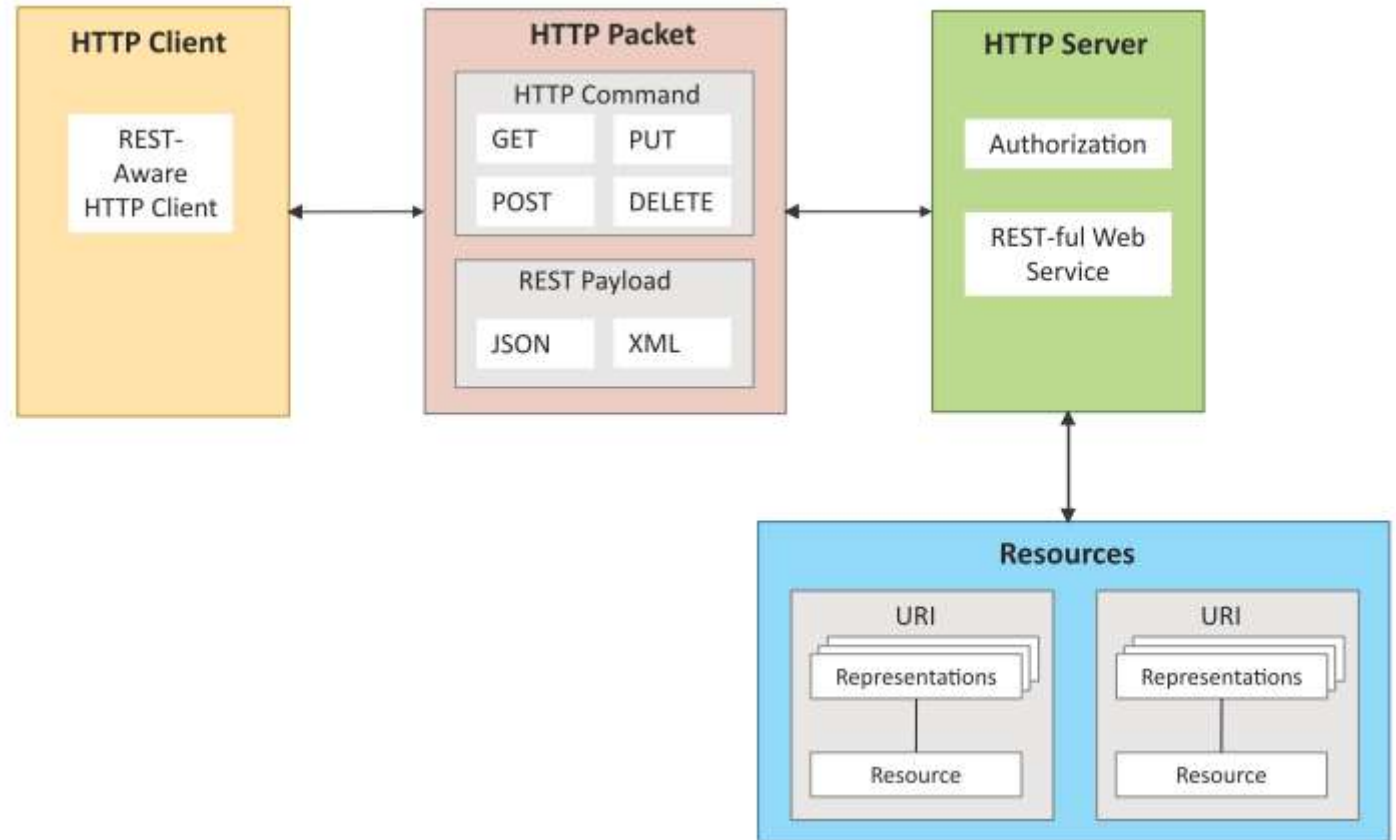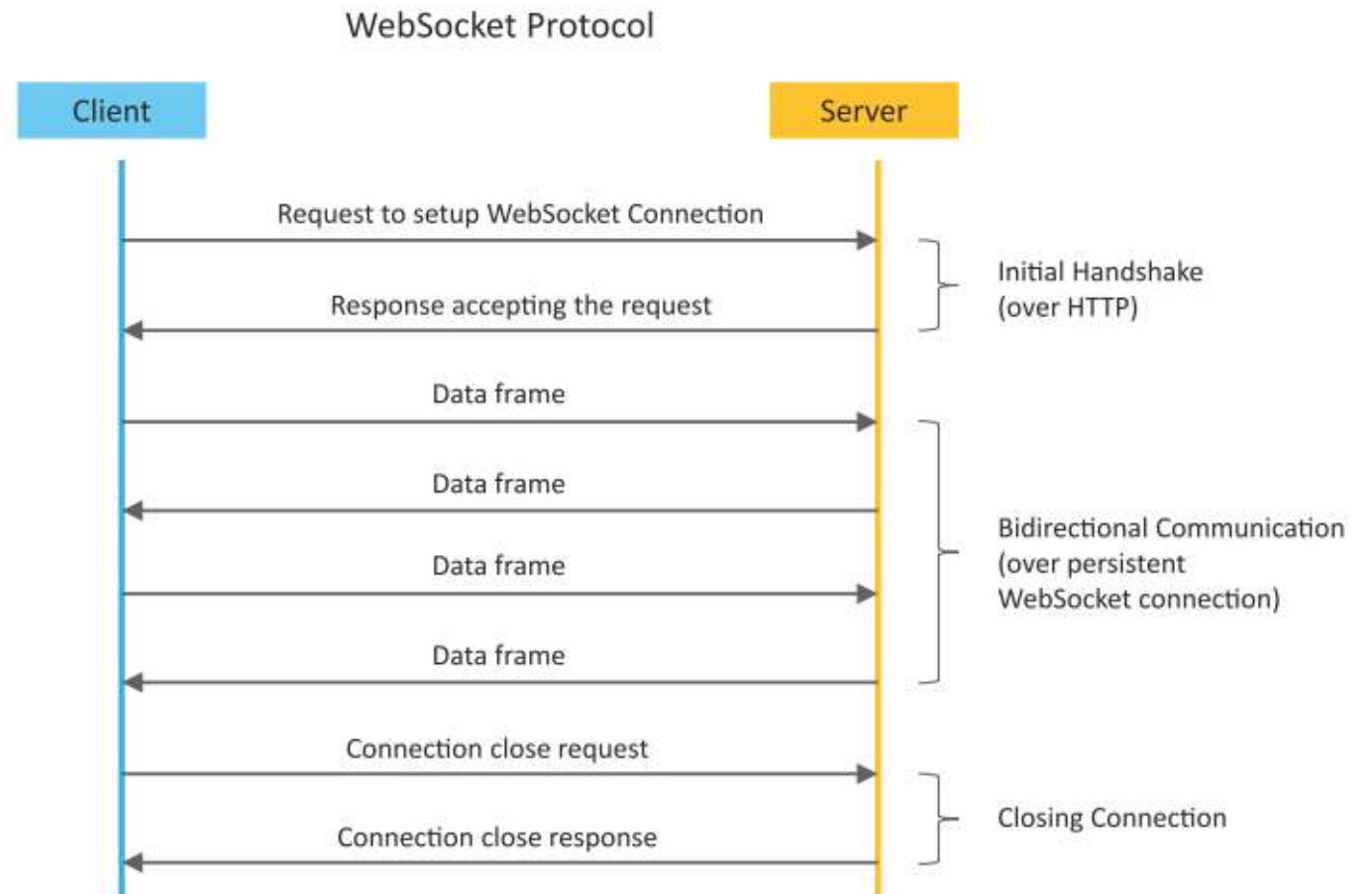
# REST-based Communication APIs Constraints

- **Client – Server**
- **Stateless**
- **Cacheable**
- **Layered System**
- **Uniform Interface**
- **Code on demand**

# WebSocket-based Communication APIs

- WebSocket APIs **allow bi-directional, full duplex communication** between clients and servers.

- WebSocket APIs follow the **exclusive pair communication model**.

## WebSocket Protocol

| Client | | Server |

Request to setup WebSocket Connection →

Response accepting the request ←

⎫ Initial Handshake (over HTTP)

Data frame →

Data frame ←

Data frame →

Data frame ←

⎫ Bidirectional Communication (over persistent WebSocket connection)

Connection close request →

Connection close response ←

⎫ Closing Connection

# Differences between REST and WebSocket-based Communication APIs

| Comparison Based on | REST | Websocket |
|---|---|---|
| State | Stateless | Stateful |
| Directional | Unidirectional | Bidirectional |
| Req-Res/Full Duplex | Follow Request Response Model | Exclusive Pair Model |
| TCP Connections | Each HTTP request involves setting up a new TCP Connection | Involves a single TCP Connection for all requests |
| Header Overhead | Each request carries HTTP Headers, hence not suitable for real-time | Does not involve overhead of headers. |
| Scalability | Both horizontal and vertical are easier | Only Vertical is easier |

# IoT Enabling Technologies

- Wireless Sensor Network
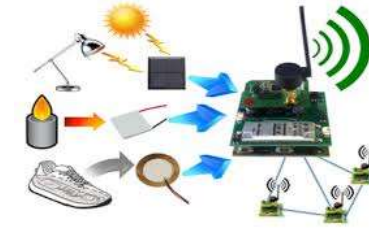
- Cloud Computing

- Big Data Analytics

- Embedded Systems

# WSN

- **Distributed Devices with sensors** used to monitor the environmental and physical conditions

- Consists of several **end-nodes acting as routers or coordinators too**

- **Coordinators collects data** from all nodes / **acts as gateway** that connects WSN to internet

- **Routers route the data packets** from end nodes to coordinators.

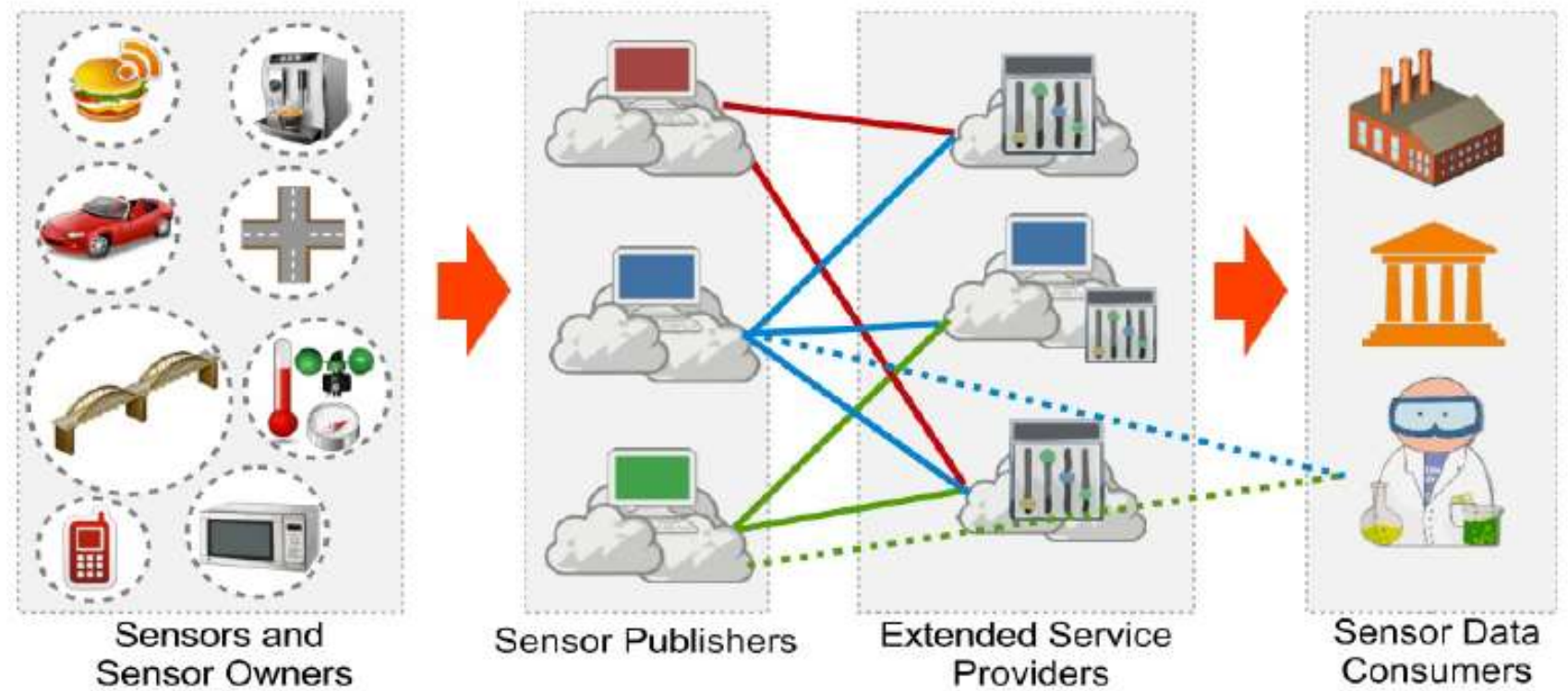# Example of WSNs in IoT & Protocols used

**Example**

- Weather monitoring system
- Indoor Air quality monitoring system
- Soil moisture monitoring system
- Survelliance systems
- Health monitoring systems

**Protocols**

- Zigbee

# IoT Technologies : Cloud (Sensing as-a-service Model)



Sensors and Sensor Owners — Sensor Publishers — Extended Service Providers — Sensor Data Consumers

# Cloud Computing

- **Deliver applications and services over internet**
- Provides computing, networking and storage resources on demand
- Cloud computing performs services such as Iaas, Paas and Saas
- Iaas : Rent Infrastructure
- Paas : supply an on-demand environment for developing, testing, delivering and managing software applications.
- Saas : method for delivering software applications over the Internet, on demand and typically on a subscription basis.

# Big Data Analytics

- Collection of data whose volume, velocity or variety is too large and difficult to store, manage, process and analyze the data using traditional databases.

- It involves data cleansing, processing and visualization

- Lots of data is being collected and warehoused
    - Web data, e-commerce
    - purchases at department/ grocery stores
    - Bank/Credit Card transactions
    - Social Network

# Big Data Analytics

**Variety Includes different types of data**

- Structured
- Unstructured
- SemiStructured
- All of above

# Big Data Analytics

**Velocity Refers to speed at which data is processed**

- Batch
- Real-time
- STreams

# Big Data Analytics

**Volume refers to the amount of data**

- Terabyte
- Records
- Transactions
- Files
- Tables

# IoT Levels and Deployment Templates

An IoT system comprises the following components:

- **Device**: An IoT device allows identification, remote sensing, actuating and remote monitoring capabilities.

- **Resource**: Resources are software components on the IoT device for accessing, processing and storing sensor information, or for controlling actuators connected to the device. Resources also include the software components that enable network access for the device.

- **Controller Service**: Controller service is a native service that runs on the device and interacts with the web services. Controller service sends data from the device to the web service and receives commands from the application (via web services) for controlling the device.

# IoT Levels and Deployment Templates

- **Database**: Database can be either local or in the cloud and stores the data generated by the IoT device.

- **Web Service**:  Web services serve as a link between the IoT device, application, database and analysis components.  Web service can be implemented using HTTP and REST principles (REST service) or using the WebSocket protocol (WebSocket service).

- **Analysis Component**: This is responsible for analyzing the IoT data and generating results in a form that is easy for the user to understand.

- **Application**: IoT applications provide an interface that the users can use to control and monitor various aspects of the IoT system. Applications also allow users to view the system status and the processed data.

# IoT Level-1

- A level-1 IoT system **has a single node/device** that performs sensing and/or actuation, stores data, performs analysis and hosts the application.

- Level-1 IoT systems are suitable for **modelling low-cost and low-complexity solutions** where the data involved is not big and the **analysis requirements are not computationally intensive.**
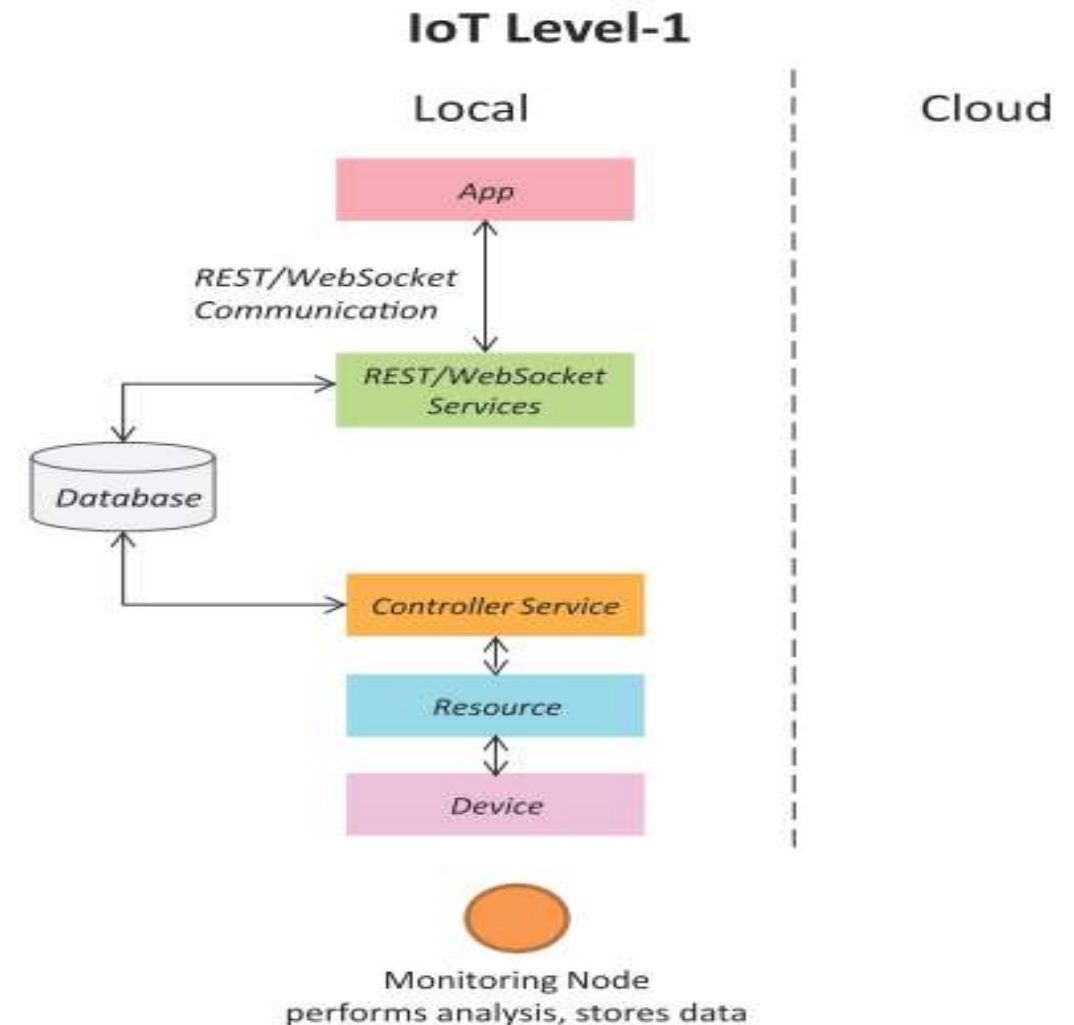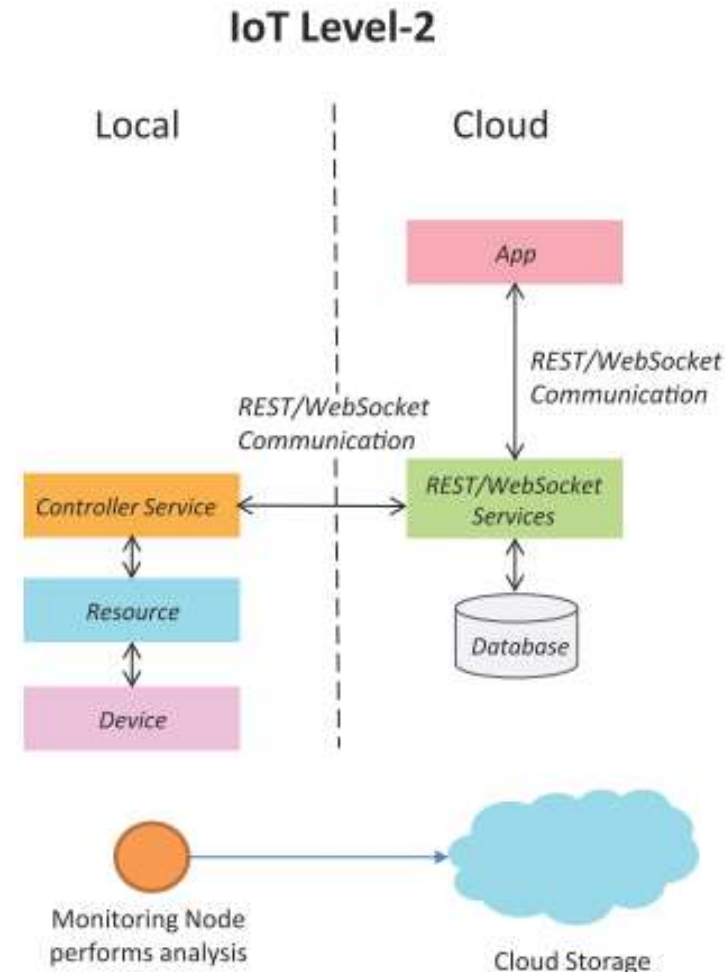
# IoT – Level 1 Example …Home Automation System
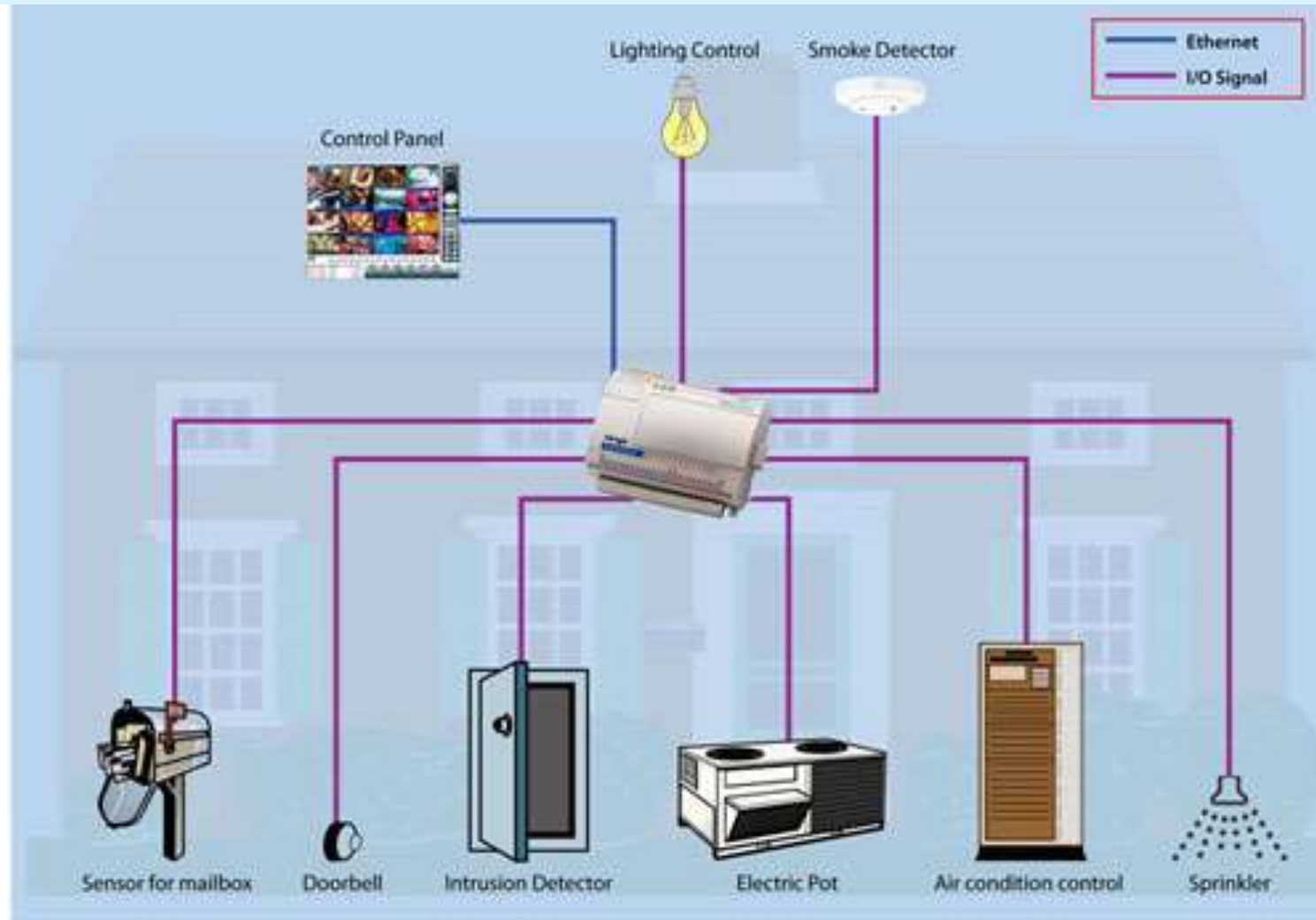
# IoT Level-2

- A level-2 IoT system has a **single node that performs sensing and/or actuation and local analysis.**

- **Data is stored in the cloud** and the application is usually cloud-based.

- Level-2 IoT systems are **suitable for solutions where the data involved is big;** however, the primary **analysis requirement is not computationally intensive** and can be done locally.



**IoT Level-2**

Local | Cloud

App

REST/WebSocket Communication

REST/WebSocket Communication

Controller Service ← → REST/WebSocket Services

Resource

Database

Device
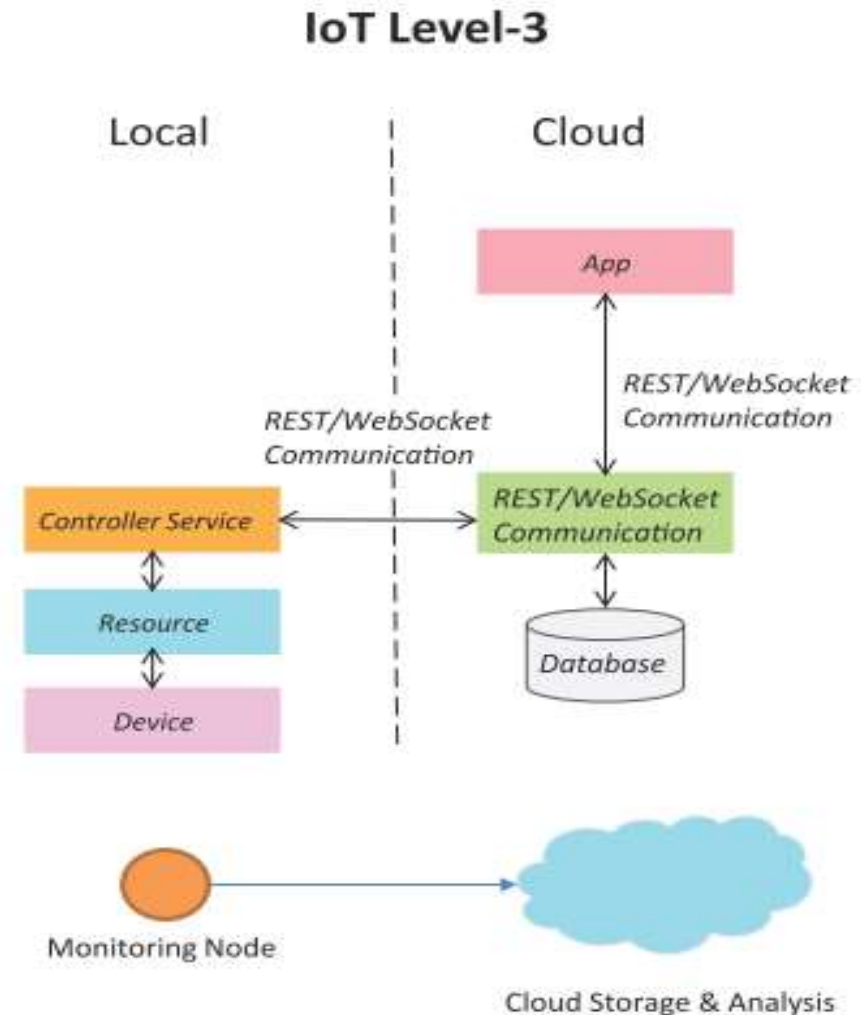
Monitoring Node performs analysis → Cloud Storage

# IoT – Level 2 Example …Smart Irrigation

# IoT Level-3

- A level-3 IoT system has a **single node. Data is stored and analyzed in the cloud** and the application is cloud-based.

- Level-3 IoT systems are suitable for solutions **where the data involved is big and the analysis requirements are computationally intensive.**

# IoT – Level 3 Example ...Tracking Package Handling

**Sensors used accelrometer and gyroscope**

# IoT Level-4

- A level-4 IoT system has multiple nodes that perform local analysis. Data is stored in the cloud and the application is cloud-based.

- Level-4 contains local and cloud-based observer nodes which can subscribe to and receive information collected in the cloud from IoT devices.

- Level-4 IoT systems are suitable for solutions where multiple nodes are required, the data involved is big and the analysis requirements are computationally intensive.
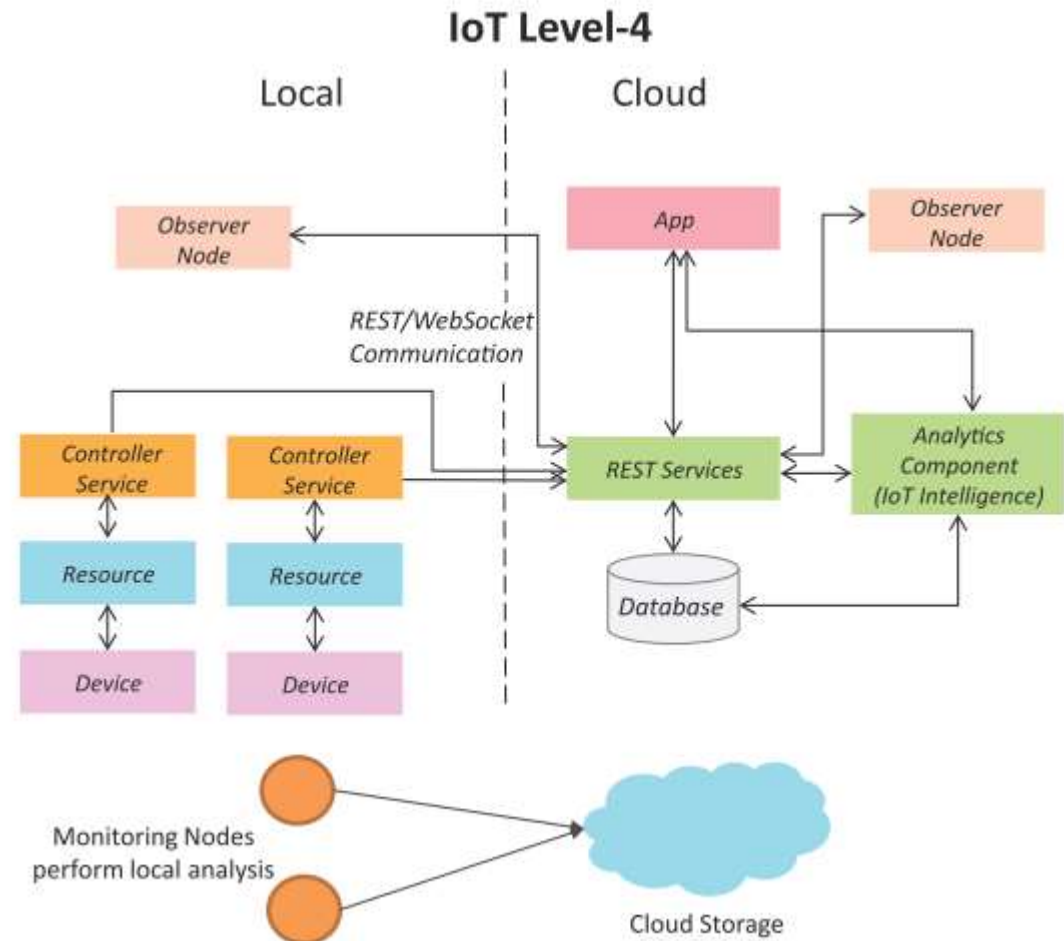
# IoT – Level 3 Example …Noise Monitoring

**Sound Sensors are used**

# IoT Level-5

- A level-5 IoT system has multiple end nodes and one coordinator node.

- The end nodes perform sensing and/or actuation.

- The coordinator node collects data from the end nodes and sends it to the cloud.

- Data is stored and analyzed in the cloud and the application is cloud-based.

- Level-5 IoT systems are suitable for solutions based on wireless sensor networks, in which the data involved is big and the analysis requirements are computationally intensive.
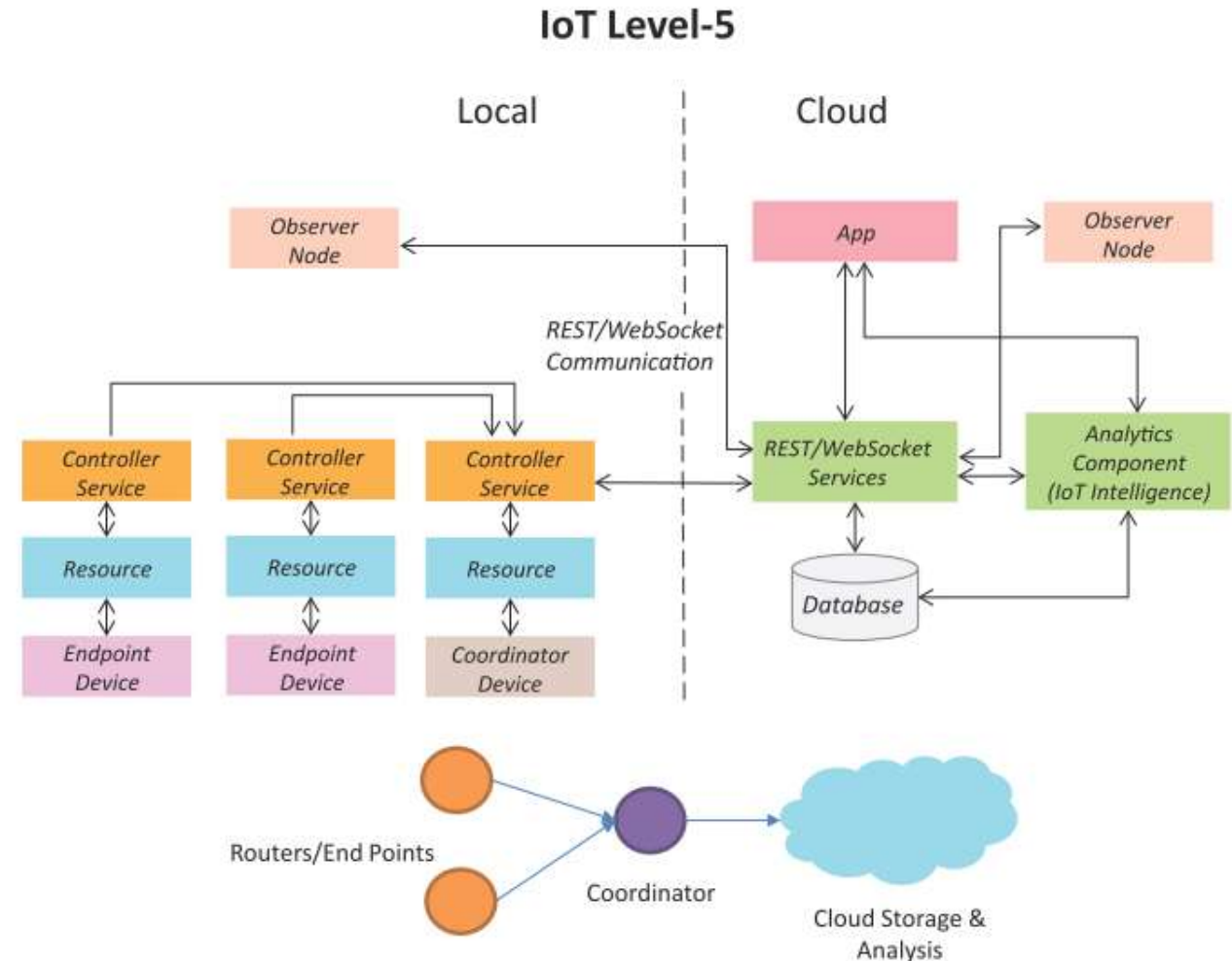
# IoT Level-6

- A level-6 IoT system has multiple independent end nodes that perform sensing and/or actuation and send data to the cloud.

- Data is stored in the cloud and the application is cloud-based.

- The analytics component analyzes the data and stores the results in the cloud database.

- The results are visualized with the cloud-based application.

- The centralized controller is aware of the status of all the end nodes and sends control commands to the nodes.
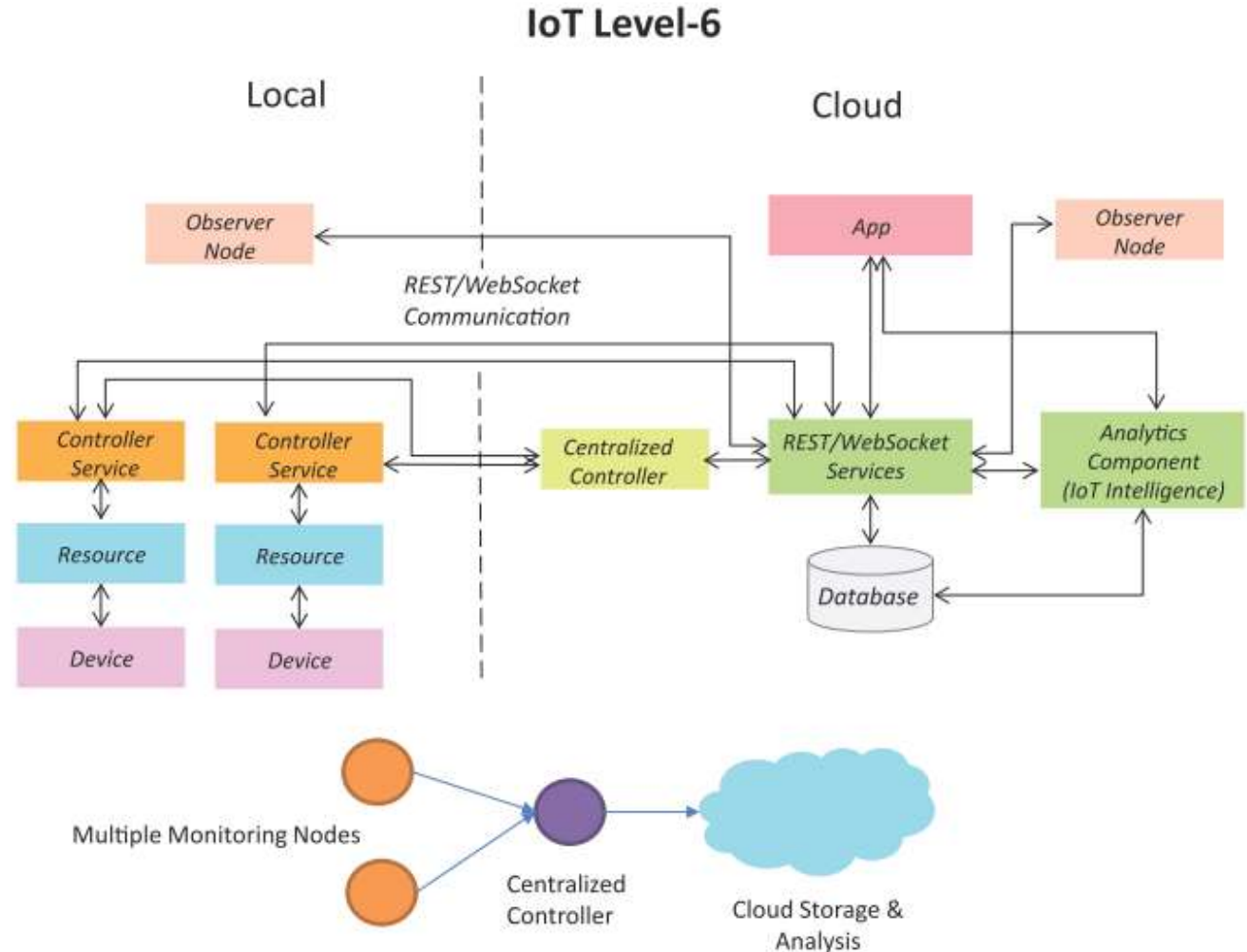
# Challenges of IoT

Connectivity

Power Management

Security

Rapid Evolution

Thank you !